SOME STUDIES ON THE NUTRITIVE VALUE OF THE SOYBEAN IN THE HUMAN DIET

DISSERTATION

PRESENTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE GRADUATE SCHOOL OF THE OHIO STATE UNIVERSITY

(Agricultural Chemistry and Soils Department)

By

W. G. BOWERS

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The Ohio State University
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ERRATA:

Foot note on this page should read; A thesis presented in partial fulfillment of the requirements **** to the Graduate School, of etc.

Note at the bottom of page 324 should read; **** Department of Agricultural Chemistry and Soils, etc.

SOME STUDIES ON THE NUTRITIVE VALUE OF THE SOY BEAN IN THE HUMAN DIET

By W. G. BOWERS

INTRODUCTORY

Extent of Production

For a great many years there has been considerable interest in the seeds of the legumes in connection with human dietetics. It is commonly known that most leguminous plants thrive under more adverse circumstances, regarding climatic conditions and soil fertility, than any other plants that furnish food products. The work of Wilforth in 1887 established the fact that they are nitrogen gatherers, collecting free atmospheric nitrogen which becomes stored as protein, and that they are almost indispensable in crop rotation. For these reasons, any leguminous plant that would furnish a human food should be of interest.

The common white or navy bean has played a very prominent role in the food problems of the United States, especially in supplying nourishment to the soldiers in the service and to the laborers on the farm and in the factory. The bean has been recommended as the "poor man's beefsteak," supplying as it does, like meat, great quantities of valuable proteins.

In China, Japan and some other of the eastern countries another legume, the soy bean, is used extensively as a human food. This plant (Glycine Hispida), now one of the most common of its familiar family, according to DeCandolle, occurred originally in the wild state in Southern Asia from the southern part of China to the southern part of Japan and as far as Java. It was cultivated and used for food in China before the time of Confucius.

A thesis presented for the degree of Doctor of Philosophy to the Faculty of the Ohio State University.

This was at least four thousand and seven hundred years ago. It has been cultivated and used for human food in Japan also for many centuries.

In Japan it is now one of the most important of the human foods, being second only to rice. That means that it plays the same role with the Japanese that meat does with the Americans or Europeans. It has been cultivated there to such an extent that a great many varieties are to be found, and it is used to such an extent in that country that Japan herself cannot supply her own requirements.

Despite the fact that the soy bean has always been so important in China, and so very important in Japan from such early times, its introduction into surrounding countries has taken place very slowly. But, with very few exceptions, wherever it has gone it has established itself permanently, and in many places it has increased in extent of production and gained eminent favor with the people.

For centuries it has been used in India as a human food, and lately its use there has remarkably increased. For several hundred years it has been the main crop in Manchuria, where raising the soy bean, making the different commercial products and exporting them, is at present the greatest industry (3). In 1910, 30% of the tillable area of Manchuria was devoted to the production of the soy bean and one billion kilograms were exported to the different countries of Europe. The product equaled about 30,000,000 bushels. In 1912 this was increased to 90,000,000 bushels. In 1910, $1,000,000 worth of soy bean products was imported into Germany, which was nearly three times as much as the year before (3).

When the plant was first carried to Europe, only two hundred years ago, it was brought as an interesting botanical specimen. It was studied as such for nearly one hundred years before anyone conceived of the idea that it was valuable as a food producing plant.

W. J. Morse (40) tells us that Professor Haberlandt, a little over a hundred years ago, began to experiment with the plant in regions of Austro-Hungary and published a work in 1878, in which he gave an enthusiastic prophesy for the soy bean and urged its cultivation. He did a good deal of work to excite interest in it as a human food, and he also at his own expense distributed a great deal of seed among the farmers of his country, but after his death the interest lagged and finally died away.

The soy bean has been grown in the United States for many years, especially in the Carolinas. Several varieties are now grown to a considerable extent in the Northeastern States. But it has been only within the last thirty-five years that it has been considered with much favor as a food for stock. Only within the last ten or fifteen years has it met with any favor at all as a food for man.

In 1916 over $5,000,000 worth of soy beans were imported into the United States (40) and in the same year about 100,000 bushels of American grown soy beans were packed as baked beans by several different canning companies in the Central and Eastern States (40). In 1917 the amount imported into the United States more than doubled that of 1916. In 1917 the

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Figures in parenthesis refer to Bibliography.

area in the United States devoted to the cultivation of the soy bean amounted to 460,000 acres. That is also probably double what it was in 1916. (40)

Several of the agricultural experiment stations thruout the Eastern States (49) have been devoting considerable time and attention to the soy bean recently, and, because of the fact that its value as a crop is being proven to be greater than many of the crops already grown, the acreage given to it has been increasing remarkably.

Human Food Preparation Made From the Soy Bean

Manchuria exports to Japan about two-thirds of her entire crop of soy beans for the manufacture of food preparations and liquid condiments. The chief liquid condiment (Shoyu) is made by mixing cooked ground soy beans, salt and water, and inoculating with a rice ferment (Aspergilus oryzae) and allowing it to stand in casks for six months or longer. The resulting sauce is a liquid of dark brown color whose odor and taste is somewhat similar to that of a good meat extract with the exception of being a little more salty and a trifle more pungent. This liquid condiment is consumed to a great extent by the Chinese as well as by the Japanese. In Japan, especially, the manufacture of the condiment is conducted on a large scale, and the yearly production (in Japan) is said to amount to nearly 2,000,000 barrels (40).

A soy milk (Toniu) is made in Japan and China by boiling the finely crushed meal in three times the amount of water for thirty minutes, and filtering thru a fine cloth filter. The separated liquid is the "Vegetable" milk so extensively used in China. Soy milk and soy milk products are being made in the United States now. Itano (22) offers the following formula: Add to the bean meal five times its bulk of water, inoculate with B-Coli and B-Lactis aerogenes as used in salt rising bread, and let stand for sixteen hours at room temperature; then boil to foaming for an hour, and filter thru cheese cloth. Add to this filtrate salt to the amount of one-half teaspoonful per quart. Unless the preparation is being made for diabetes patients he recommends the addition of five per cent milk sugar to improve the flavor. Condensed and evaporated milks are also made from the above product.

Soy bean curd (Tofu) is commonly made in Japan by the following method: Add to the milk as previously described two per cent mother liquid of sea salt; filter off the liquid; press the precipitate in a wooden frame and let the pressed curd float in a large quantity of cold fresh water in order to free the coagulum from chemicals added. This product is used as fresh Tofu, or it may be frozen and put on the market as (Kari Tofu). The frozen product may be kept for years, then used in soups, or fried (Auburaage) and eaten like fried eggs or meat.

The Chinese and Japanese make a soy bean cheese (Miso) by precipitating protein from the above described milk by the addition of magnesium or calcium salts. The grayish white curd is separated out, drained and pressed, and then allowed to ferment. This product serves as the basis of numerous fermented, smoked and dried cheeses used by the Oriental people (40).

Some American preparations are made as follows (22):

Boiled beans are prepared by soaking the beans twenty-four hours in

water (changing the water three or four times), applying hot water a couple of hours before cooking, adding one teaspoonful of soda per quart of beans and boiling in a double boiler for four or five hours.

Baked beans are prepared by treating as above and baking like other beans.

Roasted beans. Soy beans may be roasted in an oven or ordinary corn popper. They are heated until the beans are burst like popcorn. The beans thus roasted may be softened by immersing in a syrup while they are hot. This is said to make a wholesome candy. The roasted beans may be powdered and used as a salad dressing or employed as a substitute for coffee.

Raw soy bean meal is sometimes mixed with flour to make bread, biscuits or muffins. One part of bean meal mixed with four parts of wheat flour makes a palatable bread which is very nutritious. Bread made of soy bean meal alone is recommended for diabetes patients, since it contains only small amounts of starch and sugar.

Varieties and Chemical Composition

There are many different varieties of the soy bean. The varieties are based on color, size, shape and especially on the time required for the seed to mature. The early varieties are generally chosen to grow for seed and seed products.

The flavor and palatability of the different varieties of the soy bean do not appear to have been sufficiently tested. Of all the varieties grown in the cotton belt, the one said to be the most suitable for human food is the "Mammoth Yellow." It has a beautiful color which appeals to the eye. It is an excellent oil yielder and the mill operators like it because the oil is easily expressed. It yields a good looking meal, and the farmers and feeders like it because it does not show any darkness which makes them suspicious that the meal is damaged or spoiled. It is the meal from this variety which is most used as a human food in this country.

In the Ohio Experiment Station (49), about 70 varieties have been tested each year for the past six years. We have below tabulated a few of the yellow, early and prolific bearers.

Variety	Beans to 10 grs.	Blossom	Ripen	Yield in bu. per acre
Elton	55	7—25	9—24	26.51
Manchuria	68	7—24	9—16	24.21
Ohio 7496	43	7—24	9—25	28.00
Ohio 9016	53	7—25	9—25	29.22

We would judge from the above table that the Ohio 7496 and Ohio 9016 are the best varieties for the Middle Eastern States, and that the Elton and Manchuria, on account of their maturing ten days earlier, would be well fitted for the States farther North.

The "Early White" variety is said to be the most excellent variety to grow in the New England States, especially when a crop of seed is desired.

The chemical analysis of a few representative varieties are here tabu-

lated. In the eight analyses can be found the extremes in content of everything but water. They are all calculated on a uniform moisture content of 10 per cent.

Variety	Water	Ash	Protein,Nx625	Fiber	N-free extract	Fat
Itosan	10.00	4.90	39.29	3.91	26.64	15.26
Quebec	10.00	5.64	40.46	3.68	24.88	15.34
Kentucky	10.00	5.54	36.55	4.37	26.82	16.72
Medium Yellow	10.00	4.68	40.99	3.79	25.27	15.27
Manhattan	10.00	7.77	40.66	3.67	23.58	14.32
Arlington	10.00	5.19	35.07	5.81	29.55	14.38
Mikado	10.00	5.33	33.15	5.03	29.59	16.90
Hollybrook	10.00	5.73	38.49	4.28	28.44	13.06
Average	10.00	5.59	38.08	4.32	26.85	15.16

Selected from Street and Bailey (59).

The following table shows the analyses of some typical commercial soy bean flours.

	Water	Ash	Protein,Nx625	Fiber	N-free extract	Fat
Commercial soy	4.90	4.40	45.70	1.90	22.60	20.50
bean flour of some	4.20	4.20	43.10	2.20	24.90	21.40
different varieties.	3.00	5.00	42.30	5.40	24.50	19.80
These are flours	4.40	4.60	42.30	4.70	25.80	18.20
from oil extracted	7.80	4.40	39.80	3.90	24.90	19.10
cakes.	6.50	4.10	41.00	3.40	25.00	20.00
	4.60	5.10	42.90	4.20	22.40	20.80
Average	5.10	4.50	42.50	3.70	24.50	19.90

From Street and Bailey (59).

By comparing the above tables we see that the flour contains much more protein and fat and less of all other ingredients. This is probably due to bolting and other purifying processes.

Character of the Carbohydrates of the Soy Bean and Its Bearing on Nutrition

The soy bean has a variety of carbohydrates, altogether amounting to from 22% to 29% (39) (59), depending on the variety and maturity of the bean. The mature seed has no starch. The fresh green beans, those that have been dried without being allowed to ripen thoroly, or those that have ripened on the vine after the vine has been pulled show slight amounts of starch (53). In spite of the almost complete absence of starch analyses of the commercial flours made from the soy bean and put on the market for diabetes patients show from 20 to 25 per cent of nitrogen-free extract. Several authorities have found galactan in the soy bean; Lavallois (30) found as high as 11 per cent. Pentesans vary from a trace in the coarser varieties to over 4 per cent in the finer varieties. Borhehesani (7) found 3.86 per cent in one of the finer varieties, and Street and Bailey (59) found 4.94 per cent in the Hollybrook variety.

Some varieties of the soy bean have been found to contain small amounts of raffinose, Street and Bailey (59) found 1.13 per cent in the Hollybrook variety. The writers found 0.37 of one per cent in a sample of commercial soy cake meal from an unknown variety of bean. Ruhrah (53) found from nine to ten per cent of cane sugar in several different varieties. Potts (51) says he has found twelve per cent. This is not an inconsiderable amount of this kind of sugar for any kind of vegetable. It compares very favorably to the amount of cane sugar in the sugar beet when it was first cultivated for its sugar content. Street and Bailey (59) found only 3.31 per cent in the Hollybrook variety. They also found 5.73 per cent of reducing matter after hydrolysis of the malt extract. Of this, 2.59 per cent was found to be galactan and pentosan combinations. The remaining 3.14 per cent was considered as dextrin, vegetable gums and mucilages.

Character of the Fats of the Soy Bean and Its Bearing on Nutrition

The proportion of fats in the soy bean is high, ranging from fifteen to twenty per cent (23). Some Japanese experimenters have found the fats of food preparations of the soy bean to have a digestibility factor of from ninety-five to ninety-seven per cent. Their preparations are not made in such a way that the digestibility factor of fats would be increased.

According to Mathes and Dahles (32) soy bean oil contains ninety-four per cent fatty acid, eighty per cent of which is oleic, linoleic and linolenic. Then there are small quantities of free fatty acids. We would expect such an oil as this with its great amount of unsaturated fats to be very digestible. A later report by the same authors (33) gives 0.7 per cent of the soy bean oil as unsaponifiable. Of this unsaponifiable fat, one-half is solid and the other half liquid. The solid is made up of two different types of phytosterol, a substance which can easily be changed in the human body to cholesterol (26) which is of very great physiological significance to the body, even tho it does occur in small quantities.

Keimatsu (24) says that soy bean oil contains about twelve per cent of saturated fatty acids, mostly palmitic, and some stearic; eighty per cent of unsaturated fatty acids, fifty per cent of which consists of linoleic isomers. He says the oil contains two-tenths of one per cent phytosterol.

Ruatta and Testoni (54), who expressed the belief that the soy bean would become a very popular food, commented especially favorably on the amount and character of the fats as valuable in human diet. They analyzed nine varieties finding an average of 18.36 per cent of fat and, in addition to this, 1.62 per cent of lecithin.

Character of the Protein and Its Bearing on Nutrition

The protein content of the soy bean is remarkable, ranging from thirty-four to forty-five per cent in different varieties in the bean itself (43) and, of course, more in the commercial flour and soy cake meal. Not only the amount of the proteins in the soy bean products, but their excellent character, and the varieties and amounts of amino acids which they yield on digestion, make them of value as a food. The protein is mostly glycinine and yields on digestion the following amino acids (43):

	Per cent		
Glycine	0.97	Glutamic Acid	19.46
Valine	0.68	Tyrosine	1.86
Leucine	8.45	Arginine	5.12
Proline	3.78	Histidine	1.39
Phenylalanine	3.83	Lysine	2.71
Aspartic Acid	3.86	Ammonia	2.56
Tryptophane Present			

The protein of the soy bean is very similar to that of cow's milk, which yields a similar list of amino acids in the following percentages (1):

	Per cent		
Glycine	0.00	Glutamic Acid	15.55
Valine	7.20	Tyrosine	4.50
Leucine	9.40	Arginine	4.84
Proline	6.7	Histidine	2.59
Phenylalanine	3.20	Ammonia	1.61
Aspartic Acid	1.40	Serine	0.50
Tryptophane	1.50	Lysine	5.95

The milk made from the soy bean seems to be not only a nourishing food, but it serves as a check on the very prevalent summer diarrhoea common to children.

Sinclair (58) experimented on babies, who had various ailments, and found that the soy milk brought improvement in the great majority of cases, curing diarrhoea and intestinal disturbances. He found that it was easily digested and easily excreted.

Also a cheese, hard to distinguish from cow's milk cheese, has been made from the soy bean protein. In some cases cow's milk cheese has been adulterated to the extent of fifty per cent with soy bean cheese, and has been sold on the market for months before the adulteration was detected (31).

Some Japanese experimenters found in the soy bean as much as 6.9 per cent of albuminoid nitrogen. This figured in terms of protein would amount to about forty-two per cent.

The protein of the soy bean yields on digestion a complete amino acid mixture. According to Osborn and Mendel (44) rats will grow very nearly normally on glycinin. They also proved that cystine, lysine and tryptophane had to be added to any protein that does not contain them, in order to make it growth promoting. These the soy bean has. Osborn and Mendel (45) proved that the proteins of the soy bean, unlike those of other leguminous seeds thus far investigated, are adequate for promoting growth. The same authors (46) also demonstrated that if the protein of corn, which lacks the above amino acids, was supplemented with the protein of the soy bean, growth was satisfactory.

Vitamines of the Soy Bean

Daniels and Nichols (15) in their investigation of the nutritive value of the soy bean studied in a qualitative way the vitamine content. Experi-

menting with rats, they found that a diet containing sixty per cent of soy beans, the only source of the vitamines, made possible the production and rearing thru the suckling periods two successive litters of young. They found also that rats grew normally on a diet containing fifty per cent soy beans and that the females produced young at an early age.

Osborn and Mendel (44) experimented with rats with a view of determining the vitamine value of the soy bean. They used a diet of either soy cake meal or cooked soy bean meal, together with an added salt mixture of the proper kinds and amounts of different salts, pure starch, butterfat and lard. They reported that the rats completed their normal growth in the normal length of time. This shows that the soy bean has a sufficient amount of water soluble vitamine for the promotion of proper growth.

When lard entirely replaced the butter fat, the rats grew normally for over two hundred days without showing any symptoms of nutritive decline. This is much longer than the majority of rats, undergoing experiments for vitamine determination, have grown on a diet without the addition of fat soluble vitamine from some special source like butter-fat. It seems, therefore, that there is in the soy bean sufficient of the fat soluble vitamine to promote proper growth. The experimenters did not notice any eye soreness common to rats on a diet lacking sufficient of the fat soluble vitamines. The rats that had the soy meal, which did not have the fat extracted, grew a great deal better than those that had the extracted meal. So far as is known at the present time the soy bean is the only seed, with the possible exception of flax and millet, which contains sufficient amounts of both the water soluble and the fat soluble vitamines for the promotion of proper growth.

Minerals of the Soy Bean

Circumstances naturally place upon man or animal a limit to his free choice of foods. The habits of man's ancestors narrow him down to certain diets regardless of their chemical composition and the nutritive requirements of his organism. On this account he has to consume a surplus of some things in order to get sufficient of others. It has been proven that an animal will grow and fatten on less of certain food if he has free access to certain mineral salts. This being denied he will consume greater proportions of the food in order to get the salts in required amounts (17). The consideration of the mineral content of a food is assuming more importance now than ever before.

Osborn and Mendel (44) carried on a series of experiments with the view of determining the mineral content of the soy bean as related to the growth of young rats. They found that like the other seeds it is lacking in these, especially in calcium.

Dr. E. B. Forbes of the Ohio Experiment Station has given us considerable data on the mineral content of different food materials. From one of his tables we have taken the following data on the soy bean, along with three legumes generally used as foods:

	K	Na.	Ca.	Mg.	S.	Cl.	P.
Soy bean	2.095	.380	.230	.244	.444	.025	.049
Navy bean	1.390	.086	.235	.206	.224	.047	.429
Cow pea	1.636	.189	.117	.243	.280	.047	.532
Pea	.061	.563	.068	.180	.254	.024	.399

The calcium and phosphorous are the chief elements sought for in this connection. We shall notice in the table that the soy bean is second in calcium, having only 0.005% less than the navy bean, and that in phosphorus the soy bean is by far richer than the others.

The Soy Bean Compared to Some Other Legumes Used As Human Food As to Fuel Value and Organic Nutrients

Food	Fuel Value per lb.	Protein (N X 6.25) per cent	Fat per cent	Carbohydrates per cent
Navy beans	15.65	22.5	1.8	59.6
Lima beans	15.86	18.1	1.5	65.9 (5)
Cow peas	15.50	21.4	1.4	60.8
Peas	16.11	24.6	1.0	62.0
Soy beans	17.77	38.0	15.0	26.8 (59)

In this table we notice that the soy bean is superior to the other legumes in fuel value, that while its carbohydrate content is less its protein and fat contents are much greater.

Digestibility of Soy Bean Products

Obviously chemical analyses alone do not measure the nutritive value of a food. We must know also the digestibility of the food, the relative quality of its proteins, carbohydrates, fats and minerals, the extent to which accessory substances or vitamines occur, and whether for any reason it exerts a harmful influence on the body.

Some observations by Oshima on some of the Japanese food preparations indicate that the digestibility factor is high, protein 89.2 to 96 per cent, fat 95 to 97 per cent, carbohydrates, including fiber 88 to 98 per cent. The Japanese method of preparation (involving fermentation) might have some influence on the digestibility factor.

Mendel and Fine (35) found the proteins in mush prepared from soy beans to be from 74.5 to 87.6 per cent digestible by dogs and 85.3 per cent digestible by men (uncorrected for the metabolic factor). In fact, the proteins of the soy bean were only 2.6 per cent less digestible than those in a mixed diet of wheat, meat, eggs and peanut butter. The protein of the common white bean baked in the usual way was distinctly less digestible, viz., 77.9 per cent, in the human subject. The experiments of Waite on the digestibility of wheat, and of beans agree with this result. Daniels and Nicolls (15), from experiments on rats, have concluded that the proteins of the soy bean are highly efficient in promoting the growth of young animals; in fact,

about as efficient as those of milk. On the other hand, the proteins of the white bean appear to be decidedly poorer in quality or about as valuable as those of corn (34).

The nutritive quality of the white bean is further lowered by the presence of considerable amounts of carbohydrates, e.g. hemicelluloses, which are indigestible by man, and which ferment in the intestine with the production of large quantities of gas, resulting in discomfort and even in injury to the intestine because of the stretching effect of the gas (34). The carbohydrates of the soy bean appear to be more digestible and less prone to intestinal fermentation.

Mendel and Fine (35) in comparable experiments with dogs, fed in one case soy bean flour and in the other a preparation made from hulled white beans. They found five times as much crude fiber, and more than three times as much hemicellulose in the feces of the white bean fed animals, as in the feces of the soy bean fed animal. In the human subject the weight of the air dry feces from the soy bean feeding was increased only four per cent above the mixed diet period, while on the white bean diet the increase in weight of air dry feces was 68 per cent, indicating a good utilization of the nonnitrogenous material in the first case and a poor utilization in the second.

In the light of the above information it would appear that the nitrogen free extracts, as a whole, in the soy bean, as well as the protein in certain of the soy bean products, are much more highly digestible than are those of the navy bean.

EXPERIMENTAL PART

In our experimental work we propose to inquire into the digestibility of soy cake meal. We shall then determine the digestibility of the different carbohydrates as found in a representative variety of the soy bean. After passing some of the beans thru a milling process we shall study the composition and digestibility of the meal and bran and determine their relative amounts of calcium and phosphorus, and locate any possible poisons or objectionable substances that may be present in either of these. This will make it possible, then, to determine whether or not it would be profitable to carry on the milling process and eliminate certain products, or whether by the use of certain extractives we can get rid of the objectionable constituents.

The Character of the Material Used in the Experiments

In the following experiments on digestibility the samples of soy cake meal were obtained at different times from southern oil mills. What varieties or what proportions of the different possible varieties represented were not known to us. The meals were both rather coarse and somewhat gritty. Before using we ground them fine enough to pass thru a twenty mesh sieve.

For the experiments on the milled products we used a sample of the whole beans, furnished us by the kindness of the Farm Crops Department of the Ohio State University.

DIGESTIBILITY OF SOY CAKE MEAL BAKED INTO BREAD

Experiment I

The subject was a healthy man, aged 38, weight 160 pounds, engaged in moderately active laboratory work each day. Since, obviously, it is impossible to consume with relish an exclusive diet of soy bean meal, a mixed diet was selected containing a few articles of known digestibility in addition to the soy bean meal, the chief constituent. The feces from the three day experimental period were marked off with lampblack taken with the appropriate meals. Soon after collection of the stools, they were moistened with alcohol containing a little sulphuric acid, dried on the steam bath, brought to an air dry condition by exposure to the atmosphere of the laboratory and thoroly pulverized. The protein was determined by the Kjeldahl method (NX 6.25); fat by the Gephart and Csonka method (19), nitrogen free extracts, fiber and ash by the ordinary routine methods.

The soy bean meal used in this experiment had the following composition:

	Per cent
Moisture	6.5
Ash	5.7
Protein	44.1
Crude fiber	5.9
Fat	3.3
N-free extract	35.5

Two hundred grams of this meal was mixed with four hundred grams of patent wheat flour and ten grams of sugar and made into yeast raised bread. This bread was of good texture and highly palatable.

The diet for the three days was as follows, approximately one-third being consumed each day.

	Grams	Protein grams	Fat grams	N-Free Ext. grams	Calories
Soy bean meal	200	88.2	6.6	71.	696
Pat. wheat flour	400	53.2	6.0	288.	1420
Milk	3000	103.1	120.0	141.	2064
Butter	200		170.0		1530
Cane Sugar	200			200.	800
Total	4000	244.5	302.6	700.	6510
Per day	1330	81.5	100.8	233.	2170

The feces from the three days weighed 248 grams moist, and 66.6 grams air dry. They contained:

	Per cent	Grams
Moisture	7.25	4.82
Ash	19.70	13.12
Protein	27.66	18.82
Crude Fiber	8.46	5.63
Fat	22.01	14.65
Nitrogen-free Ext.	15.22	10.14

In addition to undigested food residues, feces always contain metabolic products derived, first, from the digestive fluids; and second, from mucous and epithelial cells from the walls of the digestive tract. In order to determine the amount of these metabolic products, a basal ration consisting of milk, butter, sugar, starch and agar, designed to yield feces of about the same bulk as in the soy bean period, was taken.

The diet was as follows:

3000 grams milk
275 grams butter
150 grams cane sugar
130 grams potato starch, boiled in water to make a pudding
36 grams agar, eaten dry and raw*

One-third of the above was consumed daily for a three-day period.

The resulting feces weighed 270 grams moist and 55.6 grams air dry and contained:

	Per cent	Grams
Moisture	5.36	2.98
Ash	19.50	10.85
Protein	11.90	6.60
Fat	31.20	17.34
Crude fiber	1.40	.77
N-free extract	30.60	17.03

The protein in the feces of this period represents metabolic products from the digestive juices and intestinal walls as well as some unabsorbed protein from the milk. Deducting this from the protein eliminated in the feces during the soy bean period we have 18.82 — 6.60 = 12.22 grams, which represents the unabsorbed protein from the wheat flour and soy bean meal. This gives a coefficient of the total protein of the bread of 91.5. Assuming that protein of patent wheat flour is 88.6 (64) per cent digestible, the coefficient of digestibility of the soy bean meal protein becomes 93. This is hardly fair, however, since the coefficient 88.6 was obtained without making a correction for metabolic products in the feces. We feel safe in concluding, however, that soy bean meal, prepared as in this experiment, is as digestible as regards its protein as is the protein of fine wheat flour which stands supreme among the cereal grains in this respect.

The carbohydrates of bread made from fine wheat flour are 97.7 per cent absorbed in man (47), milk sugar 99 (5) per cent and cane sugar probably 100 per cent. Using these values, the Nitrogen-free extract of the soy bean meal is found to have a coefficient of digestibility of 96.9 per cent.

DIGESTIBILITY OF SOY CAKE MEAL MUSH

Experiment II

In this experiment the soy bean meal was prepared as a porridge by

*Agar had 6.35 per cent ash and 15.75 per cent of moisture.

cooking five hours in a double boiler. This sample of meal contained more grit than that used in Experiment I, but not enough to increase the ash content greatly. It had the following composition:

	Per cent
Moisture	4.17
Ash	5.80
Protein	49.31
Crude fiber	5.10
Fat	6.50
Nitrogen-free extract	29.12

The diet for the three day period contained the following, approximately one-third being eaten each day:

	Grams	Protein grams	Fat grams	N-Free Ext. grams	Calories
Milk	2000	70.	80.	94.	1376
Butter	150		127.5		1147
Cane sugar	300			300.	1200
Soy bean meal	370	182.	24.	108.	1375
Total	2750	252.	231.5	502.	5098
Per day	917	84.	77.2	167.	1699

The fecal residue from the above food weighed 224 grams moist and 58.1 grams air dry, and contained the following:

	Per cent	Grams
Moisture	4.40	2.56
Ash	20.64	11.19
Protein	39.90	23.20
Crude fiber	7.00	4.06
Fat	18.96	11.00
N-free extract	9.00	5.22

Assuming that 6.06 grams of protein represents the unabsorbed protein of the milk plus the metabolic protein from the digestive fluids, etc., an assumption that cannot be far from the truth, then the unabsorbed protein from the soy bean meal must be $23.20 - 6.60 = 16.60$ grams. This gives a coefficient of digestibility for the protein of the soy bean meal of 90.90. If the carbohydrates of milk are 99, and cane sugar 100 per cent absorbed, then the coefficient of digestibility for the nitrogen-free extract of the soy bean meal is 96.

In this experiment, as in Experiment I, we cannot calculate accurately the digestibility of the fat, but we are not particularly concerned with that phase of the subject at this time. By adopting proper experimental procedure, one might determine satisfactorily the digestibility of soy bean fat, but for that purpose the amount of the experimental fat should be largely increased while other fats in the diet should be reduced to a minimum.

It appears from these experiments that the digestibility of soy bean meal, prepared as a bread by mixing with wheat flour, or as a porridge, is highly digestible by man, the factors from the two experiments being 91.3 and 90.9 for the proteins, and 96.9 and 96 for the carbohydrates.

A STUDY OF THE NUTRITIVE VALUE OF THE NITROGEN FREE CONTENTS OF THE SOY BEAN

As described on page 289, we found the digestibility of the carbohydrates of the soy bean as a whole to be 96 per cent. According to the estimates of Oshima (47) (51) and others, the digestibility of the carbohydrates of different varieties of the soy bean seems to vary widely. It would be only reasonable to suppose that the wide difference in these determinations was due to the fact that different varieties were used in the various cases. Then, too, these differences might be accounted for by two factors; first, the same carbohydrates might have different digestibility factors in the different varieties of the bean; second, the different combinations of the various carbohydrates in the different varieties most undoubtedly would have different digestibility factors. (60) (25) (14) (29) (55).

But the first factor, in the opinion of the writer, would be of very little significance, while the second would be the one most likely to be responsible for the difference.

By references given above (53) (51) (59), we see that one variety may have as much as twelve per cent of sucrose, while others have only three. The amounts of starch, dextrin, pentosans, galactans, waxes, fiber, etc. might also vary in like proportions. Consequently, a variety with much sucrose or dextrin and little of the waxes or fiber would be likely to have a high digestibility factor for its nitrogen free extracts, while one with high wax or fiber content and low sucrose or dextrin would have a low one.

It is our purpose in this investigation to determine the digestibility factor for each different carbohydrate in a certain sample of the soy bean. We shall consider it fair to assume that these factors hold good for all varieties. So, when we have determined the different carbohydrates of a sample, we can estimate the digestibility of the carbohydrates as a whole.

There are some carbohydrates peculiar to the soy bean and to some other materials used for food, like cane molasses, cotton seed meal and a very few others. On the assumption that it is of interest from a biochemical standpoint to know how digestible is the raffinose and other rather peculiar carbohydrates of the soy bean, we are giving this data.

Kuriyama and Mendel (27) have determined that raffinose is digestible in dogs and rats, but that the greater part of the digestion takes place in the large intestine. Later Kuriyama (28) found that the sterile extract of feces of man, pig, dog, rabbit and guinea pig, having raffinose in their diet, usually contain small amounts of raffinose.

In the following experiments, we made duplicate determinations on one variety of the material *meal No. II in the foregoing experiments. In the following described work, we determined the different carbohydrates in the sample according to the methods used by Street and Bailey (59), with few departures, and our description emphasizes only the departures.

Determination of the Parts in the Meal

After removing the fat with petroleum ether (boiling point 75°C) from 20 grams of the material, the fat free meal was boiled for eight hours with 95 per cent alcohol under a reflux condenser. After filtering, the residue was dried and weighed (weighing 16.06 grams), and preserved for further determinations. Twenty grams more of the same sample, after having the fat extracted in the same way, were extracted for sixteen hours in a percolating extractor with 95 per cent alcohol and, in this sample was left 15.6 grams of the residue when dried. The entire filtrate in each case was evaporated almost to dryness, made up to 200 cc. with water and the mixed materials separated into two divisions by precipitating the organic acids, waxes, etc., by means of basic lead acetate.

Two drops at a time of a saturated solution of the acetate were applied until a small amount of the filtered solution gave no further precipitation. About two cubic centimeters of the lead acetate were required. The excess of lead was removed by adding one cubic centimeter saturated solution of anhydrous sodium sulphate. Then, by filtering, we obtained the rather straw-colored solution containing the water soluble and the alcohol soluble carbohydrates.

The Determination of the Carbohydrates Not Precipitated by the Lead Acetate

In this solution made up to 200 cc. we made reduction tests and took polarization readings as follows:

The copper reduction test as applied before inversion yielded an almost negligible result. An aliquot of 50 cc, corresponding to 5 grams of the original material, yielded only 0.0072 grams Cu_2O, equal to 0.06 per cent of invert sugar. After inverting 100 cc. of the solution, by treating with 5 cc. concentrated hydrochloric acid and allowing to stand over night, aliquots representing 5 grams of the original material yielded 0.3750 grams Cu_2O, equal to 3.68 per cent of sugar calculated as invert sugar and sucrose.

Before inversion, polarization readings were taken and calculated to normal condition. We used the equivalent of 20 grams of the original material in 200 cc. of the filtrate, which was taken as the basis upon which to make the calculations. This gave us a concentration of 20:200 or 10:100. The normal concentration was taken as 26.048. Therefore, the readings we obtained were taken as 10/26.048 of the normal. Our results averaged 1.49° Ventzke. 1.49 = 10/26.048 of 3.9. Hence, our normal direct reading was 3.9° V. After inversion with hydrochloric acid over night, calculating in the same manner, we obtained an average reading of —1.1 V. Our readings were taken in a 20 mm. tube at 22° C.

A sucrose solution having a direct polarization reading of 3.9° should have after inversion a reading of —1.6 V. Our invert reading, —1.1, indicates that there is present a simple sugar, or a complex one which hydrolizes into dextrorotary sugars, which offset the levular rotation. This sugar, if a complex one, can be neither dextrose nor maltose. These sugars would have had more reducing power in the original unhydrolized mixture. This could be none of the simple sugars. Levulose would cause a still greater

levular rotation. Dextrose or galactose would have exercised a greater reducing power than was found in the original solution.

We applied the Emulsin Test for the presence of raffinose (41). We added 0.5 gram of emulsin to 50 cc. of the direct solution and 50 cc. of water, and the mixture was kept at a temperature of about 40°C for two hours. This gave a decided increase in reducing power over a similar preparation which had been boiled to prevent the action of the enzyme. We concluded as did Street and Bailey (59) that this sugar must be raffinose and applied Creydt's formula for estimating sucrose and raffinose.

In the formula:

a = direct polarization
b = invert polarization

$$\text{Sucrose} = \frac{0.5188\ (a—b)}{0.8452} = 3.03 \text{ per cent}$$

$$\text{Raffinose} = \frac{a—\text{sucrose}}{1.852} = 0.47 \text{ per cent}$$

These two sugars after inversion amount to 3.5 per cent. By reduction they amount to 3.68 per cent.

The Determination of the Materials in the Lead Precipitate

After subtracting the 6 per cent or 1.2 grams of fat extracted by means of benzine, and the 3.65 per cent, or 0.7 grams of sucrose and raffinose, extracted with 95 per cent alcohol, we had a remainder of 18.1 grams. Of the original 20 grams so extracted we had a residue of 16.06 grams. This leaves 2.04 grams or 10.2 per cent of the original material to be expected in the lead salts.

The lead precipitate was decomposed with hydrogen sulfide. The hydrogen sulfide gas was passed thru a paste, made of the precipitate by using just enough water to wash the precipitate from the filter. The precipitate was washed thoroly with water and the washings were added to the filtrate. The clear filtrate was then warmed sufficiently to remove the excess of hydrogen sulfide. After the hydrogen sulfide had been removed the remainder was made up to 200 cc and the organic acid content determined, according to Schulze (57). Aliquot parts of 50 cc. were evaporated to about half their volume; treated with 2 or 3 cc. of a saturated solution of strontium hydroxide and 150 cc. 95 per cent alcohol; heated on a steam bath and filtered while hot. The precipitate was ignited to the oxide and titrated with a standard citric acid. It required 0.08 grams of citric acid to neutralize the equivalent of five grams of the original substance. This gave a percentage of 1.6 citric acid. We reckoned all the organic acid content as citric acid.

In one aliquot of the above liquid the pentozans were determined (official method 42) and found to be 0.9 per cent. The remaining 7.5 per cent of the alcohol extract was reckoned by difference as waxes, color substances, etc.

Materials in Cold Water Extract

The alcohol extracted residue for each of the two portions amounted to 16.06 and 15.60 grams respectively. This was digested with 200 cc. cold water for thirty-six hours. During this time the digests were protected from bacterial decomposition by means of a film of toluene. At the end of the time the water extracts were partially evaporated at a temperature of 60°—70° C. We kept the temperature below 70° in order to prevent a possible hydrolysis which might occur on account of the slight acidity of the material, and above 50° to dissolve soluble starch. After the partial evaporation, a little sodium carbonate was added to neutralize the faint acid reaction. The solution being opalescent, we treated as usual with lead acetate, and then made the solution up to 200 cc.

The direct polarizations calculated on a basis of normal conditions were 12.90° Ventzke in the first portion, and 12.86° in the second. The invert polarizations were 6.50° and 6.40° respectively.

The copper reduction tests on the water extracts before inversion were entirely negative in both cases. After inversion aliquots, representing 1 gram of the original substances, yielded 0.1655 and 0.1660 grams Cu_2O for the two samples respectively. The average of these two (0.1658) according to the "Munson and Walker's Table" is equivalent to 0.0736 grams of dextrose. The molecular weight of dextrose is 180 and the molecular weight of dextrin is less by one molecule of water or 18. Therefore, we reduced the 0.0736 one-tenth of itself which left 0.0663 grams to be considered as dextrin. This is 6.63 per cent of the original substance. We estimated this fraction of the carbohydrates as dextrin because its behavior with the 95 per cent alcohol, the Fehling's Solution and the polarimeter, shows that it is for the most part dextrin and vegetable gums, with some possible soluble starch and hemicelluloses.

The Disaccharides or Trisaccharides would have been extracted with the 95 per cent alcohol or would have reduced Fehling's Solution before inversion had they been present. The monosaccharides all have the power of reducing Fehling's Solution directly. Since no such reduction took place, we feel justified in concluding that none of them were present. The iodine test (blue coloration of the dried residue from water extract) for soluble starch was negative.

It will be shown later what quantities of the hemicelluloses were present.

Dextrins have specific rotations from +195° to +215°, while dextrose has one of +52.5°. Hence, our dextrin estimate of 6.5 per cent, which had a direct reading of +12.9° and an invert one of +1.2° V. This, figured to normal conditions, is equal to 7.5° and shows that the carbohydrates of the water extract are for the most part dextrin, vegetable gums and mucilages.

MALT DIGESTION

The residue from the cold water extraction, which now weighed 13.15 grams, was digested with freshly prepared MALT EXTRACT for two ninety minute periods as is the custom. The solution was then hydrolized and

aliquots reduced and the results figured to the equivalent of starch, and a percentage of 0.54 of starch found. The residue from the malt material was then dried and weighed, weighing 12.22 grams.

ONE PER CENT HCl EXTRACT

Half of the malt extracted residue was boiled with a one per cent solution of hydrochloric acid for one hour under a reflux condenser. Copper reduction determinations were made on aliquots of the extract, and calculated from the cuprous oxide to a dextrose equivalent. The results were 6.42 per cent and 6.58 per cent respectively. This gives us an average of 6.5 per cent for the hydrochloric acid extract by this method.

To get further evidence as to the amount of copper reducing substances, and to gain definite data concerning their character, determinations of pentosan and galactan were made. The pentosans were determined according to the official method (42).

One-fourth of the malt extracted residue yielded .1995 grams of pentosans for the aliquot. This is equivalent to 3.99 per cent of the original material.

The galactans were determined according to the official method (42). The remaining fourth of the malt extracted residue yielded 0.1260 grams of galactan. This is 2.52 per cent of the original material.

By adding the percentages of the pentosans (3.99) and the galactan (2.52), we get 6.51 per cent for the sum of the two. In order to determine how this sum compares to the results of the copper reduction method, we calculated the copper reduction results in terms of pentosans and galactans

The relation of the pentosans and galactans to glucose is (10):

$$(a)\ \frac{\text{Glucose}}{\text{arabinose}} = 1.032$$

$$(b)\ \frac{\text{Glucose}}{\text{galactose}} = 0.898$$

The relation of the pentosans and galactans to the sum of the two is 8/13 and 5/13 respectively.

(c) 8/13 of the copper reduction, $6.5 = 4$.

(d) 5/13 of the copper reduction, $6.5 = 2.5$

Substituting and transposing in the formulas (a) and (b) respectively,

$$\frac{4,\ (c)}{1.032\ (a)} = 3.88 \text{ Pentosans equivalent.}$$

$$\frac{2.5,\ (b)}{0.898\ (d)} = 2.77 \text{ Galactans equivalent.}$$

$3.88 + 2.77 = 6.65$, the percentage of copper reduction products calculated to the proper pentosan—galactan equivalent. This very nearly checks with the 6.51 per cent, the sum of the pentosan and galactan determinations.

Sodium Hydroxide Extract

The hydrochloric acid residue which now weighed 3.255 grams was boiled for thirty minutes with sodium hydroxide 1.25 per cent. The filtrate was neutralized, clarified and hydrolized. The reduction tests yielded no cuprous oxide. The residue was now dried and weighed, amounting to 0.6 grams.

True Cellulose from the Chlorinated Residue

The sodium hydroxide residue was moistened with water; treated with chlorine gas for one hour; washed with water; boiled in a solution of 2 per cent sodium sulfite and 0.2 per cent sodium hydroxide; washed, and dried. The residue, weighing .48 grams, was estimated on the basis of the original material and amounted to 4.8 per cent true cellulose.

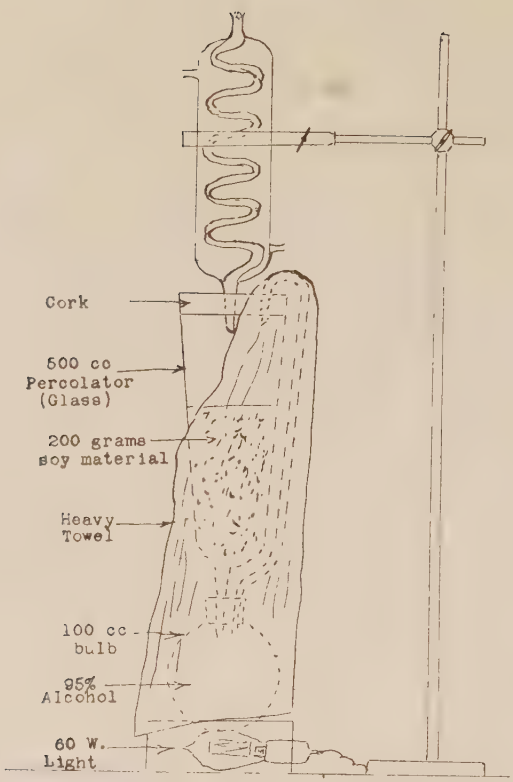
Waxes, Resins, Tannins, Color Substance, etc.

The sum of the carbohydrates and fiber as determined in the above described fractions amounts to 24.70 per cent. Deducting this from the 34.22 per cent of nitrogen-free extract, found in the original meal, leaves a remainder of 9.58 per cent. From the 95 per cent alcohol extract, where we would expect to find the waxes, resins, etc., we obtained by difference, 7.50 per cent. The difference of 2.08 per cent, if distributed among the other ten determinations, would give on an average of 0.2 per cent shortage in each case. This might reasonably come within the range of experimental error, and so we searched no farther for substances in any other than the 95% alcohol extract.

Some general qualitative methods were applied on the 95% alcohol extracts as we obtained them on a much larger scale than we did in the above experiments. (See figure on following page.) Aliquots of the extract were divided into two divisions by means of basic lead acetate as above described, and the tests made on each division. Tests for resins and tannins, in the portion soluble in water and not precipitated by lead acetate, were all negative. Tests for resins and tannins in the fraction insoluble in water and precipitated by lead acetate were all positive.

Taking for granted that the small amount of color substances made no difference as far as nutritive value is concerned, no effort was made to determine these quantitatively. The tests for tannins were so faint in each case that we decided to defer the quantitative determinations for the bran and the meal, as we expected later to study them separately.

For the determination of the resins, we use the official method as applied to vanilla extracts (42), excepting that we weighed the precipitate made by the acid (HCl) on the caustic potash solution. For an aliquot representing 5 grams of the original substance, the dried residue weighed .0355 grams. This is 0.71 per cent of the soy meal used. The behavior of the remainder of the material in the previous processes (Insoluble in benzine, soluble in alcohol, insoluble in water, etc.) indicated that it is made up of vegetable waxes, and by difference it amounts to 6.79 per cent.



Apparatus for extracting meal with 95 per cent alcohol.

Summary Table of the Results

Hot 95 per cent alcohol extract	
Soluble in water and not precipitated by lead acetate.	
Invert sugar	0.06
Sucrose	3.03
Raffinose	0.47
Insoluble in water and precipitated by lead acetate.	
Pentosans	0.90
Organic acids (as citric)	1.60
Waxes, color principals etc.	9.52*
Cold water extract	
Reducing matter after hydrolysis calculated as dextrin (including .6% pentosan, and 0.65% galactans)	6.65

*The difference between the above determined amounts of various carbohydrates, fiber, etc. and the 34.22 per cent N free extract as determined in the meal II.

Malt extract	
Starch	0.54
One per cent hydrochloric acid extract	
Galactans 2.52%, Pentosans 3.99%	6.65
One and twenty-five hundredths per cent NaOH extract	
Reducing sugars	0.00
Chlorinated residue or true cellulose	4.80

Digestibility of the Nitrogen Free Contents

In this experiment the soy bean meal was prepared as a porridge by cooking for five hours in a double boiler. This sample of meal contained some grit but not enough to increase the ash content greatly.

It had the following general composition:

	Per Cent
Moisture	4.17
Ash	5.80
Protein	49.31
Crude fiber	5.10
Fat	6.50
Nitrogen-free extract	29.12

The diet for the three-day period contained the following, approximately one-third being eaten each day:

	Grams	Protein grams	Fat grams	N-free Ext. grams	Calories
Milk	2,000	70	80	94	1,376
Butter	150		127.5		1,147
Cane Sugar	300			300	1,200
Soy bean meal	370	182	24	108	1,375
Total	2,750	252	231.5	502	5,098
Per day	917	84	77.2	167	1,699

The fecal residue from the above food weighed 224 grams moist and 58.1 grams air dry, and contained the following:

	Per cent	Grams
Moisture	4.40	2.56
Ash	20.64	11.19
Protein	39.90	23.20
Crude fiber	7.00	4.06
Fat	18.96	11.00
N-free extract	9.00	5.22

Determination of the Carbohydrates of the Feces from a Diet on the Above Sample of Soy Meal

The methods used in these determinations were the same as those used in the bean sample.

The direct polarization of the 95 per cent alcohol solution was —2.34°, and the invert reading was 0. Copper reduction of the solution before and after inversion amounted to nothing worth taking into account. This showed no sucrose nor raffinose. In the light of this we assumed that the —2.34 direct polarization was due to a small amount of cholesterol which, by hydrolysis, was changed to an organic acid which gave the 0 reading after inversion (2).

Finding no sucrose nor starches to interfere, we determined the pentosans and galactans on the original substances without making the various extractions.

Tabulation

	Per cent
Hot 95 per cent alcohol extract.	
Organic acids as citric acid	2.12
Waxes, color, etc.	3.60
Invert sugars	0.04
Sucrose	0.00
Raffinose	0.00
Cold Water Extract.	
Soluble starch	0.00
Reducing matter (calculated as dextrose)	0.37
Malt Extract.	
Starch	0.00
One per cent hydrochloric acid extract.	
Pentosans and galactans on original unextracted material	
Pentosans	2.67
Galactans	0.80
One and twenty-five hundredths per cent sodium hydrate extract.	
Reducing sugars	0.00
True celulose	6.40

Digestibility of the Materials in the Nitrogen Free Contents

The amount of invert sugar in the meal was small. It was relatively larger in the feces than in the diet. Since there is a possibility of invert sugar coming into the feces from other sources than from ingested food, it would hardly seem worth while to make any calculations as to digestibility in this case.

We obtained no evidence of sucrose in the feces, which would show that the sucrose of the meal is perfectly digestible. The fact that we got no evidence of the presence of raffinose in the feces would not necessarily prove the same in this case. The splitting off of the fructose, with dilute hydrochloric which we might expect to be complete in the stomach digestion, would leave melibiose, a reducing sugar that would reduce the Fehling Solution before inversion, and the amount would show up in the 0.04 per cent of reducing sugar. The 0.04 per cent, if all considered from this source, would indicate a high digestibility factor for the melibiose. The fact that 0.04 per cent comes well within the range of experimental error in digestibility experiments would argue that the raffinose has a high digestibility factor in this case.

Our tables show 2.12 per cent of organic acids. This equals 1.23 grams in the feces. They show 1.60 per cent in the meal, which equals 5.90 grams. These figures give a digestibility factor of 80 per cent for the organic acids. This is without metabolic correction. We found 2 per cent organic acids in the base ration feces. Taking this from the 2.12 per cent in this case and estimating the digestibility with the 0.12 per cent that is left, we get a digestibility factor of 99 per cent for the organic acids. This is with metabolic corrections.

The waxes, etc. were determined by difference in case of the meal and also the feces. So the chances for error in the determination are multiplied by as many times as we have other determination, which amount to at least eight. Then, the basis on which we estimated them by difference (the Nitrogen free extract in case of the original meal and feces) was in each case found by difference. So the chances for error here were multiplied by four. With so many chances for error in the determination of the waxes, and so many in the determination of the basis on which we should estimate the percentage of digestibility of them, we would consider it unfair to use the figures in the tables in undertaking this. But, since the figures would give us a factor of 94, and no other factors seem to be robbed by it, we would be safe in saying that the waxes, etc. have a high digestibility.

Digestibility of the Materials in the Cold Water and Malt Extracts

In the meal we found all the reducing matter after hydrolysis to amount to 6.65 per cent of the original. Six-tenths of a per cent of this was found to be pentosans. Sixty-five hundredths of a per cent was found to be galactans. That left 5.4 per cent to be reckoned as dextrins. In the feces we found all of the reducing matter after hydrolysis to amount to 0.37 per cent. We did not undertake to determine the pentosans and galactans included in this reducing matter, for we saw that it would make a difference of only a few tenths of a per cent above 99 for the factor of digestibility of the dextrins.

Since we found no trace of starch in the feces, we concluded that what little starch there was in the meal was completely digested. This is what we would expect of any starch so thoroly cooked as this had been.

Digestibility of the Pentosans, Galactans and True Cellulose

Adding together the percentages of pentosans found in the different extracts of the bean meal, we have 5.49 per cent in the original meal. What we determined as pentosans in the feces amounted to 2.67 per cent. Using these figures in estimating the digestibility, we get 92.8 per cent. Since the 2.67 per cent was obtained from the feces without making any previous extractions, we thought it fair to make the same determination on the feces of the basal diet. We found in that 0.62 per cent. Making correction for this we get a factor of 94.2 per cent.

All the galactans of the meal amount to 3.17 per cent of the original meal. All the galactans of the feces amount to 0.8 per cent. Using these figures in the estimation of the digestibility of these carbohydrates we get a factor of 96.2 per cent.

The chlorinated residue or true cellulose of the meal equals 4.8 per cent or 17.7 grams. That of the feces equals 6.4 per cent or 3.7 grams. Using these figures in estimating the digestibility we get a factor of 79 per cent. This seems like a high figure for the digestibility of any cellulose. We realize that there are some chances for error in this determination, but our figures cannot be far from correct in these cases for we notice that the 4.8 per cent in this estimation is only a 0.3 less than the 5.1 determined in the original meal by the official method. There was but six-tenths difference in the two methods used in the feces.

MILLING OF THE SOY BEAN

Composition of Parts

For several years the nutritive value of wheat bran and patent wheat flour, when considered separately has furnished an interesting and practical study. In 1879 Rubner (52) showed that the nutritive value of wheat bread becomes lower as the bran content increases. In 1890 Wicks (62) found by experiments with undecorticated wheat flour and decorticated wheat flour that the bread of the decorticated wheat flour was more thoroly uti ized than that of the undecorticated. Woods (64) has found by similar studies that the digestibility factor for standard patent flour was: Protein 88.6 per cent and carbohydrates 97.7 per cent. He found the factors for graham flour: Protein 74.9 per cent and for carbohydrates 89.2 per cent. From these figures we would have to conclude that the wheat bran is hardly at all digestible by man.

As for other materials than wheat not so many offer the possibilities of separation into bran and pure flour or meal, and not so many appear to have been studied in this regard. Brionx (8) compares the nutritive value of ground peanut shells and peanut bran. He finds peanut bran much less digestible than peanut meal, but much better than peanut shells. He finds that when the shells and bran are mixed in different proportions that the shells depreciate the nutritive value of the bran very much. His experiments were performed on cattle, but the comparison serves to give us an idea of what might be the case with man.

Fuchs (18) says that there is in peanut bran 14—17 per cent protein and 14—18 per cent fat. The shucks contain less protein (3—6%) and less fat (6—7%) and are 70 per cent digestible. He thinks the mixture would make a good cattle feed.

Accepting this and recalling the fact that the navy bean bran is so indigestible and is responsible for fermentation and discomforting gas in the digestive system, we were led to the effort to separate the bran and the meal of the soy bean and make determinations of the nutritive value of each taken separately. We soon found that by the slow and tedious process of peeling the bran off the bean with an ordinary knife, we could make a complete separation. But, on account of the process being so tedious, we did this for only a limited number of beans of average size in order to determine the percentage of bran on the bean.

When the separation was made we found the bran to constitute 8% of

the whole bean, the remainder being cotyledon and germ. We found that we could easily with the same means separate the germs and determine their percentage. We found the germ to constitute 1½ per cent.

We found in this process that the bran did not adhere very tightly to the cotyledon, and we planned to carry on the process on a larger scale with mills similar to those used for wheat. By courtesy of Farm Crops Department of The Ohio State University, we obtained access to a set of small flour mills of the roller type, one of coarse adjustment and one of fine. With these we milled a considerable portion of the beans. We passed the beans thru the coarse rollers twice, then sifted thru a coarse sieve. This separated most of the bran, having in it a small amount of the cotyledonous material. Most of the meal went thru the sieve and contained some of the bran. Then, the first bran was passed thru the finer rollers and sifted thru the same coarse sieve, and that which passed thru the sieve was put with the first meal. Then, all of the meal was passed thru the finer rollers twice and sifted thru a fine sieve. That which did not pass thru the fine sieve was placed aside as middlings. We used only the first bran and the last meal in the following experiments.

The bran consisted of very large flakes. We had to grind it thru a burr mill three times before it would pass thru a twenty mesh sieve. The meal was finer than necessary to pass thru the sieve.

The meal had the following composition:

	Per cent
Moisture	8.23
Ash	4.60
Fat	18.01
Protein	40.99
Crude fiber	1.70
Nitrogen-free extract	26.47

The bran had the following composition:

	Per cent
Moisture	8.46
Ash	4.42
Fat	1.50
Protein	5.81
Crude fiber	37.00
N-free extract	42.81

Digestibility of the Bran

In the digestibility experiment, the subject was a man thirty-eight years old, weighing 150 pounds, 5 ft. 8 inches high, enjoying good health and working at the ordinary laboratory routine. The diet consisted of the following, divided equally among the three days of the diet period:

3000 cc. whole milk, 4% fat, 3.5% protein, and 4.5% carbohydrates.
207 grams butter fat

200 grams cane sugar
100 grams potato starch, pure, well cooked
100 grams soy bean bran cooked for one-half hour in boiling water into a thin mush.

Subject felt no ill effects whatever thruout the entire period of one day previous to diet, the three days' diet period and one day following. Feces were regular every morning, but were slightly hard. The feces of the three days' experimental period was marked off by a capsule of carmine taken with the appropriate meals, and in the moist state weighed 210 grams. The stools were each treated as in previous experiments, and weighed when air dry 60 grams. The analyses were carried out as in previous experiments.

The composition was as follows:

	Per cent
Moisture	7.31
Ash	22.23
Fat	24.11
Protein	12.40
Crude fiber	20.30
N-free Extract	13.65

Since the amount of protein and fat in the bran amount to so little in each case, we considered it not worth while to determine the digestibility of these constituents of the diet.

The carbohydrates and the crude fiber are the prominent components of the bran material, and so we deemed it sufficient to determine the digestibility in these two cases only.

The Digestibility of the Nitrogen-Free Extract

The 13.65 per cent of nitrogen free extract in the feces, or 8.1, grams based on the 60; diminished by the 1 per cent or 1.49 grams, based on the 140 grams of milk sugar ingested; equals 6.79 grams, nitrogen free extract in the feces. This, based on the 42.81 grams of nitrogen free extract in the 100 grams of the bran used in the diet, leaves a residue of 15.8 per cent and a digestibility factor of 100—15.8 or 84.2 per cent. This is much less than the digestibility factor for the nitrogen free extract of the soy bean as a whole, (96.9) as determined previously by us. This is due, very likely, to the large proportion of waxes, etc. in the bran.

Digestibility of the Crude Fiber

We found in the feces of the bran diet 20.3 per cent of crude fiber, which was 12.18 grams based on the 60 grams of the feces. There was 37 per cent, or 37 grams of crude fiber in the 100 grams of bran in the diet. Using these figures, 37 as the base and 12.18 as percentage, we get 32.9 per cent of the undigested fiber. This gives 100—32.9 or 77.1 per cent for a digestibility factor for the crude fiber. This figure seems high for a fiber, but it is only 2—4 per cent higher than we found for the fiber in our previous experiments on the whole meal, and 2 per cent lower than found for true cellulose.

Physical Effects of a Diet Solely of the Mush Made From the Bran

In order to see what would be the physical effects of a day's diet on the bran alone, we made three meals of 30 grams each for one day. Next day we were a little uncomfortable on account of a slight amount of gas in the bowels. We were a little weak and very hungry but not sick. The next day the stool was voluminous but not so very soft. The diet had neither a laxative nor a constipating effect that could be noticed.

The Calcium Oxide and the Phosphorus Pentoxide Content of the Soy Bran and Soy Meal

Osborn and Mendel (44), in the same series of experiments in which they determined the vitamine content of the soy bean, made some determinations as to the mineral content as related to the growth of rats. They found it somewhat lacking in calcium.

In our consideration of the food value of the meal and bran separately, we endeavored to determine whether or not we could increase the ratio of calcium by making use of the meal alone as food. We made quantitative determinations of the Calcium Oxide (according to the Official Method) (42) in the bran and in the meal separately. We found the CaO of the bran to be 0.80% and that of the meal 0.27%. Counting the bran 8% and the meal 92% of the whole bean, we arrived at the amount of CaO in the whole meal as follows:

$$
\begin{aligned}
8/100 &= \text{ratio of bran to whole product} \\
92/100 &= \text{ratio of meal to whole product} \\
0.80 &= \text{per cent CaO in bran} \\
0.27 &= \text{per cent CaO in meal} \\
8/100 \times 0.80 &= 0.064 \text{ bran's share of the CaO} \\
92/100 \times 0.27 &= 0.248 \text{ meal's share of the CaO} \\
0.064 + .248 &= 0.31, \text{ the percentage of CaO in the whole meal.}
\end{aligned}
$$

The proportions of Calcium Oxide in the meal, and the bran, are somewhat similar to the proportions of Calcium Oxide in the wheat flour and the wheat bran, that of the wheat flour being about 0.025%, and that of the wheat bran about 0.14%. But, the amounts are much larger in the soy products in each case. The CaO of the soy bean taken as a whole is about twice as large in amount as that of the common pea, (that for the pea being about 0.14%), and a little larger than that of the navy bean (that being about 0.22%), also greater than that of the cow pea, (a relative to the soy bean having about 0.18%) (56).

Of the nonmetallic inorganic substances in a food material, the phosphates are undoubtedly the most important (56). Rations, balanced according to nature, like milk and eggs have relatively large proportions of these. Many of the seeds and cereals have small quantities in relation to the organic food contents. Considering this, and recalling that wheat bran has a much larger phosphorus content than has wheat flour (56), we decided to make quantitative determinations of the Phosphorus Pentoxide in both the bran and the meal of the soy bean. By application of the Official Method (42) in several samples, we found the P_2O_5 of the bran to be 0.27% and that

of the meal to be 1.52%. Following the same method of calculation for the P_2O_5 in the whole meal as we did for the Calcium Oxide, we found 1.42%, for the whole meal. We then found the P_2O_5 in the whole meal and found it to be only 0.04% less than the above figure.

The removal of the bran raised the P_2O_5 content from 1.42% to 1.52%, or an increase of 0.10%. This is not enough to make any difference as to the removal of the bran, for the P_2O_5 is increased only one-fifteenth of itself by the removal of the bran.

The proportions of P_2O_5 in the soy bran to that in the soy meal is opposite to that in the wheat bran and the wheat flour. In the soy meal it is five times as great as it is in the soy bran. In the wheat flour it is one-fifteenth as great as it is in the wheat bran, being 20% P_2O_5 in the wheat flour while it is 3.0% in the wheat bran. This amount of P_2O_5 in the whole bean is about seven times as great as it is in the wheat flour. It is one-half as great again as it is in the cow pea, (1.0%) and a little greater than it is in the common navy bean, (1.14%) (56).

TOXIC AND DISAGREEABLE OR UNPALATABLE SUBSTANCES OF THE SOY BEAN

Some Investigations as to the Possible Poisons

A great many of the different leguminous seeds are poisonous. The castor bean and the Burma bean are noteworthy examples. It is generally conceded that if one could eat enough of the common navy bean raw, it would have a poisonous effect. A great many people parboil and discard the first water from the navy bean, considering it to be poisonous. Pammel (48) says that the Repe Beans of the Scarlet Runner are poisonous.

Joseph Burtt-Davy (16) describes several species of Crotalaria, a legume with some characteristics like the soy bean, which are poisonous to stock. He describes the symptoms and the results of the diseases. Watt (61) says that he has known horses to die after eating the dried peas of the Lathyrus Sativus—"Muttar."

Church (13) says that a paralysis has been induced in man by Muttar. Chestnut (12) says that Crotalaria Sagatallis L.—"Rattlebox"—a legume found in the Central United States, has been known to poison horses.

Pammel (48) says that the soy bean can be fed to animals in small quantities only, on account of its purgative properties. He says that a loss of considerable number of cattle occurred in England recently, where soy bean cake had been used. When the soy products were fed mixed no trouble was caused, but when fed alone they were poisonous.

H. C. Brill (9) says that twenty-five samples of soy beans and a large number of other beans were tested by the Ferric Chloride test and Jorrison's test, and that the soy beans from Japan gave positive tests for Salicylic Acid, while Chinese, American and Philippine beans gave either negative or slightly positive tests. None of the soy beans gave Jorrison's test after they were fermented.

A. C. Whittier (62) gives an account of trouble with soy bean hay as a roughage for animals. He found by extracting the hay that there was a

poison, poisonous to guinea pigs. The extract that was poisonous to the guinea pigs was made with a 70-80% alcohol and water solution and precipitated with lead acetate. We are of the opinion that the above described poisonous effects were due to something that developed in the products on standing, especially when we find that Kiyohisa Yoshimma (65) found the three ptomaines: Inidoazolylethylamine, Tetramethylenediamine, Pentamethylenediamine in decomposed soy bean products.

It is possible too that the small amount of poisonous substances that have been suspected to be present in the soy to such an extent that they cannot be made to constitute an entire ration for stock, would be cooked out as well as fermented out in the preparation of food for man.

It has been suggested (4) that there is a slight trace of HCN in the soy bean meal.

We made the following Cyanide tests to see if we could detect the presence of cyanide:

Iodin solution test, negative with both bran and meal.

Mercuric Chloride test, negative with both bran and meal.

Guaic Acid and Copper Sulphate test negative with both bran and meal.

Sodium Picrate Paper was not reddened by the gas evolved from either bran or meal, either before or after being treated with sulphuric acid. So it seems as tho there is no HCN or cyanides of any kind present in the bran or the meal of the samples we tested.

Street and Bailey (59) suggest that there might possibly be tannins present in the soy bean. We made the following tests for tannin on the bran and meal separately:

Ferric chloride gave a very little milky color, but this did not disappear on heating. (This resulted the same way for both bran and meal.) We obtained a similar result from the whole meal.

Alcohol solution of Thymol and concentrated sulphuric acid gave very slight pink with meal but no test with bran.

Iodine in neutral solution gave negative results in case of both bran and meal.

Ammonium Chloride and Ammonia gave negative results in both cases.

Potassiumferricyanide gave slighest red with the meal, but nothing with the bran.

Not being satisfied with the qualitative tests, we made the official quantitative tests (gravimetric) and in four cases with the meal gave an average of 0.004% and the bran nothing. It seems that whatever amount of tannin there is in the soy bean is found in the cotyledon and not in the bran.

After removing the protein from the alcohol solution extracted from both the meal and the bran, we got a positive test for a slight trace of alkaloids with each, Mercury-potassium Iodide, and Phosphotungstic Acid, and Phosphomolybdic Acid in both the meal and bran. Not enough alkaloids in either case to call for quantitative determination.

In our tests for salicylic acid, we got negative results in case of both the bran and the meal.

Location and Elimination of the Disagreeable and Unpalatable Substances

Like a great many other food materials the soy bean may be destined to undergo a period of unpopularity on account of its peculiar flavor. It would seem very unfortunate if a food as highly nutritious, and as free from harmful elements as is the soy bean, would fail to take an important place in our diet. But, it seems as though a good many of us are not inclined to relish it in its common form.

In most of the Japanese foods made from the soy bean the disagreeable flavor is avoided by the nature of the preparation made. These, for the most part, involve some sort of fermentation which changes the flavor entirely. The Domestic Science Department of the Ohio State University has carried on considerable experimentation making different preparations, combinations and extractions, as well as making use of different methods of cooking soy bean preparations, to avoid the disagreeable flavor. Phillips, in a piece of work in the laboratory of the Department of Foods and Nutrition in the Ohio State University, experimented by extracting with hydrochloric acid in order to remove the flavoring substance. He succeeded in obtaining a product that had an excellent taste, but the hydrochloric added removed a great deal of the valuable food matter.

Wishing to avoid loss of valuable food material as much as possible, we attempted to locate the disagreeable flavors in some physical part such as the bran or germ which could be removed and otherwise utilized; or in some chemical constituent, such as the oil or acids which might be extracted and used commercially. Such attempts inevitably called for many tests as to flavor. We realized that the people on whom we could call to make the tests were working under different conditions as to exercise and diet, and could not be relied upon for uniform decisions. So we conceived the idea of obtaining a selection of small animals, keeping them under uniform conditions, allowing them free access to the different products; and judging the tastes according to the amount the animals consumed.

Thinking of the minute differences that might not show up with the various products, if we considered the consumption of each individual we made record of the daily consumption per gram animal.

For our experiments we selected rats to which to feed the different products, because they seem to have a very delicate sense of taste, and they appear to uniformly approve or disapprove of different flavors. From the fact that rats are found wherever man is found, and are not found elsewhere, and from the fact that they consume man's food, we would judge that as far as matters relating to their foods are concerned the tastes of rats coincide fairly well with our own.

For the sake of comparison, in our attempts to locate the substance or substances responsible for the flavor of the soy bean, we treated the different parts and products of the navy bean the same way. In many cases we conducted the tests on the two side by side, feeding three rats on each product of the soy and navy bean for three days at a time. In the selection of these rats for each test, we selected one a little less than half grown, one a little more than half grown, and one full grown. This proved to be a good selection, for the reason that the full grown ones appeared to

be willing and able to tide over the period of distasteful food better than the young and growing ones, and the very young ones appeared to be more sensitive to the slight disorders attending a diet which is not up to the standard in nutritive qualities. This further necessitated our taking into consideration the size of the animal and making our estimate per gram rat.

In order that a supply of food might be before the rats all of the time thruout the three days and yet be in a condition to enable us to determine, from day to day, how much each rat consumed, we made it into a paste. We used no water in the paste for it would evaporate more or less and fermentation would take place before the three-day period had passed. We found butter good for this purpose altho we had to use a mixture of thirty-three per cent in order to make the food pasty enough to stick together. This amount of butter was found not to interfere with the comparative flavors of the various products.

We supplied each rat constantly with something in the nature of greens or succulent vegetables, so that the diet would not be too concentrated for their physical condition and so that the water soluble accessory, which might not be present in every diet that we gave, would not be entirely wanting. We found raw potato the best in this regard, not because it had the most of the vitamines, but because the rats would eat it better than other things of this kind. We numbered the six rats I, II, III, IV, V and VI, which numbers we maintained thruout the entire series of experiments, feeding each rat in a separate cage.

The following data, altho all excepting that of Experiment I is summed up in average, was taken from extended notes in which were recorded the weight in grams of food consumed each day by each rat separately, and the weight of each rat at the beginning and at the end of each three day's diet period, and also the physical condition of each rat as best we could determine from external appearances as here recorded in I.

The data here noted is followed by a series of charts which show at a glance the desirability of the different food products for the same six rats, as they were allowed to eat as much as they chose from each preparation. We drew our conclusions as to the relation of the flavors from the relative amounts consumed by the rats.

EXPERIMENT I

In the first experiment each of the six rats was fed a balanced ration for three days. It was known to contain everything necessary for the promotion of growth. It consisted of: casein, dextrin, salts, agar, butter fat and water extract of oats. Rats were known to relish this diet, and so they were fed on it to determine how much they would consume per day. About 5 grams of green clover was also given to each rat to determine whether they had any inclination to depart from the balanced ration.

	Day	Wt. of rat	Grams consumed	Remarks
Rat I	1	75	6	Ate no clover
	2		7	Ate no clover
	3	77	6	Ate no clover
Rat II	1	143	8	Ate no clover
	2		9	Ate no clover
	3	144	10	Ate no clover
Rat III	1	219	12	Ate no clover
	2		12	Ate no clover
	3	219	12	Ate no clover
Rat IV	1	176	10	Ate a little clover
	2		11	Ate no clover
	3	177	10	Ate a little clover
Rat V	1	176	10	Ate half clover
	2		10	Ate no clover
	3	178	11	Ate no clover
Rat VI	1	75	7	Ate no clover
	2		6	Ate no clover
	3	77	6	Ate no clover

Rats averaged 0.63 grams food per gram rat per day.

Before recording the following experiments, we found that none of the rats would eat navy bean meal mixed with water, and they would eat very little of the soy bean meal so prepared.

EXPERIMENT II.

Soy Cake Meal

Rats I, II, and III were fed on a diet consisting of 67 per cent soy cake meal, and 33 per cent butter mixed into a paste. Approximately 5 grams of clover also were given each rat.

Average daily consumption per gram rat, 0.038.

Average gain in weight per rat, 0.00%.

Condition of rats at end of three days diet period, slightly irritable.

Rats IV, V and VI, were fed on a diet consisting of 67 per cent different sample soy cake meal, and 33 per cent butter mixed to a paste. About 5 grams of clover also were given to each rat.

Average daily consumption per gram rat, 0.035.

Average gain in weight per rat, 0.17%.

Condition of rats at end of three days diet period, slightly irritable.

EXPERIMENT III.

Whole Soy Bean Meal and Whole Navy Meal

Rats I, II and III were fed on a diet consisting of 67 per cent whole meal made from the soy bean, and 33 per cent butter, made into a paste. Approximately 5 grams of green alfalfa were given to each rat.

Average daily consumption per gram rat, 0.033.

Average gain in weight per rat, 0.25%.

Condition of rats at end of three days diet period, irritable and hungry.

Rats IV, V and VI were fed on a diet consisting of 67 per cent whole meal made from navy beans, and 33 per cent butter well mixed into a paste. About 5 grams alfalfa to each rat.

Average daily consumption per gram rat, 0.021.

Average gain in weight per rat, 0.00%.

Condition of rats at end of three days diet period, very irritable.

EXPERIMENT IV.

Soy and Navy Bean Bran-Free Meal

Rats I, II and III were fed on a diet consisting of 67 per cent pure navy bean meal, bran free, and 33 per cent butter, mixed into a paste. Approximately 5 grams of raw potato were given to each rat.

Average daily consumption per gram rat, 0.022.

Average gain in weight per rat, 0.08%.

Condition of rats at end of three days diet period, very irritable.

Rats IV, V and VI were fed on a diet consisting of 67 per cent pure soy bean meal, bran free, and 33 per cent butter, mixed into a paste. Approximately 5 grams of raw potato were given to each rat.

Average daily consumption per gram rat, 0.030.

Average gain in weight per rat, 0.25%.

Condition of rats at end of three days diet period, very irritable.

EXPERIMENT V.

Soy and Navy Bean Bran

Rats I, II and III were fed on a diet consisting of 67 per cent navy bean bran, separated from the cotyledons, and 33 per cent butter, mixed into a paste. Raw potato was given as in previous experiments.

Average daily consumption per gram rat, 0.036.

Average gain in weight per rat, 0.25%.

Condition of rats at end of three days diet period, somewhat bloated, feces soft.

Rats IV, V and VI were fed on a diet consisting of 67 per cent soy bean bran and 33 per cent butter, mixed into a paste. Raw potato was given as in previous experiments.

Average daily consumption per gram rat, 0.043.

Average gain in weight per rat, 0.33%.

Condition of rats at end of three days diet period, feces soft.

EXPERIMENT VI.

Benzine Extracted Soy and Navy Bean Meal

Rats I, II, and III, fed on a diet consisting of 67 per cent navy bean meal, benzine extracted, and 33 per cent butter, mixed to a paste. Raw potato was given as in previous experiments.

Average daily consumption per gram rat, 0.026.

Average gain in weight per rat, 0.00.

Condition of rats at end of three days diet period, feces small and hard.

Rats IV, V and VI, were fed on a diet consisting of 67 per cent soy bean meal, benzine extracted, and 33 per cent butter, mixed to a paste. Raw potato was given as in previous experiments.

Average daily consumption per gram rat, 0.031.

Average gain in weight per rat, 0.17%.

Condition of rats at end of three days diet period, feces small and hard.

EXPERIMENT VII.

Alcohol Extracted Soy and Navy Meal

Rats I, II, and III, were fed on a diet consisting of 67 per cent ether and alcohol extracted soy bean meal and 33 per cent butter, mixed into a paste. Raw potato was given as in previous experiments.

Average daily consumption per gram rat, 0.035.

Average gain in weight per rat, 0.00.

Condition of rats at end of three days diet period, normal.

Rats IV, V and VI, were fed on a diet consisting of 67 per cent ether and alcohol extracted navy bean meal and 33 per cent butter mixed to a paste. Raw potato as in previous experiments.

Average daily consumption per gram rat, 0.040.

Average gain in weight per rat, 0.08.

Condition of rats at end of three days diet period, normal.

EXPERIMENT VIII.

Balanced Ration

For the purpose of finding out how much the rats would eat of a diet they liked, and which was nutritious, we fed all six of the rats on a diet consisting of:

Corn meal 66 per cent, soy meal 22 per cent, and alfalfa leaf meal 12 per cent. Then on the whole mixture, 67 per cent and 33 per cent butter mixed into a paste. Raw potato was given each rat as in previous experiments.

0.058 grams of this ration, per gram rat per day, were consumed by the six rats during the three days' diet, with an average gain of 0.44 per cent per rat.

All rats were in normal condition in every respect, so far as we could determine.

EXPERIMENT VIII b.

Cooked Soy and Navy Meals

In the following experiments we fed rats I, II, and III, on whole soy meal that had been cooked in boiling water for four hours. This means of treatment raised the average daily consumption from 0.033 to 0.037 per gram rat.

When the navy bean was so treated, rats IV, V and VI, increased their average daily consumption from 0.021 grams to 0.045 grams per gram rat.

EXPERIMENT IX.

16% Soy and 2% Navy Bean Oils

Rats I, II, and III, were fed on a diet consisting of 67 per cent of balanced ration as in experiment VIII, 33 per cent of butter and to this 16 per cent of soy bean oil. Raw potato was given as in previous experiments.

Average daily consumption per gram rat, 0.040.

Average gain in weight per rat, 0.17%.

Condition of rats at end of three days diet period, rat II sick, others normal.

Rats IV, V and VI, fed on a diet consisting of same as above, excepting all the navy bean oil that was extracted from 50 grams of meal was put in 50 grams of the balanced ration as above.

Average daily consumption per gram rat, 0.058.

Average gain in weight per rat, 0.56%.

Condition of rats at end of three days diet period, normal.

EXPERIMENT X.

4% Soy and 4% Navy Oils

Rats I, II, and III, were fed on a diet consisting of 67 per cent of balanced ration as in Experiment VIII, 33 per cent of butter and to this 4 per cent of soy bean oil. Raw potato was given as in previous experiments.

Average daily consumption per gram rat, 0.050.

Average gain in weight per rat, 0.25%.

Condition of rats at end of three days diet period, normal.

Rats IV, V and VI, were fed on a diet consisting of 67 per cent of balanced ration as in experiment VIII, 33 per cent butter and to this 4 per cent of navy bean oil. Twice as much as in previous experiments.

Average daily consumption per gram rat, 0.049.

Average gain in weight per rat, 0.35%.

Condition of rats at the end of three days diet period, normal.

EXPERIMENT XI.

Alcohol Extracted Sugars of Soy and Navy Beans

Rats I, II and III, were fed on a ration consisting of 67 per cent balanced ration as in experiment VIII, 33 per cent butter and the alcohol extracted sugar that came from the soy bean, in same percentage as they came out of the soy bean.

Average daily consumption per gram rat, 0.055.

Average gain in weight per rat, 0.48%.

Condition of rats at end of three days diet period, normal.

Rats IV, V and VI, were fed on a diet consisting of 67 per cent balanced ration as in experiment VIII, and 33 per cent butter and the alcohol extracted sugar that came from the navy bean, in same percentage as they came out of the navy bean.

Average daily consumption per gram rat, 0.046.

Average gain in weight per rat, 0.40%.

Condition of rats at end of three days diet period, normal.

EXPERIMENT XII.

Organic Acids of Soy and Navy Beans

Rats I, II, and III, were fed on a ration consisting of 67 per cent balanced ration as in previous experiments, 33 per cent butter and the organic acids that came out of the bran.

Average daily consumption per gram rat, 0.044.

Average gain in weight per rat, 0.17%.

Condition of rats at end of three days diet period, restless.

Rats IV, V and VI, were fed on a diet consisting of 67 per cent balanced ration as in previous experiment and 33 per cent butter and the organic acids that came from the navy bean, in same percentage as they came out of the bean.

Average daily consumption per gram rat, 0.045.

Average gain in weight per rat, 0.08%.

Condition of rats at end of three days diet period, restless.

EXPERIMENT XIII.

Waxes from Soy and Navy Bean

Rats I, II and III, were fed on a diet consisting of 67 per cent balanced ration as in previous experiments, 33 per cent butter, and the waxes, etc., that came from the soy bean, in the same percentage as they came from the bean.

Average daily consumption per gram rat, 0.045.

Average gain in weight per rat, 0.17%.

Condition of rats at end of three days diet period, normal.

Rats IV, V and VI, were fed on a diet consisting of 67 per cent balanced ration as in previous experiments, 33 per cent butter, and waxes, etc., that came from the navy bean, in the same percentage as they came out.

Average daily consumption per gram rat, 0.048.

Average gain in weight per rat, 0.17%.

Condition of rats at the end of three days diet period, normal.

EXPERIMENT XIV.

Water Extracted Soy and Navy Bean

Rats I, II and III, were fed on a diet consisting of 67 per cent water extracted soy meal and 33 per cent butter.

Average daily consumption per gram rat, 0.037.

Average gain in weight per rat, 0.08%.

Condition of rats at end of three days diet period, normal.

Rats IV, V and VI, were fed on a diet consisting of 67 per cent water extracted navy bean meal and 35 per cent butter.

Average daily consumption per gram rat, 0.035.

Average gain in weight per rat, 0.08%.

Condition of rats at end of three days diet period, slightly irritable.

EXPERIMENT XV.

Water Extract of Soy and Navy Beans

Rats I, II and III were fed on a diet consisting of 67 per cent balanced ration as in Experiment VIII, 33 per cent butter, and the water extract that came from the bean.

Average daily consumption per gram rat, 0.056.

Average gain in weight per rat, 0.35%.

Condition of rats at end of three days diet period, normal.

Rats IV, V and VI fed on a diet consisting of 67 per cent balanced ration as in Experiment VIII, 33 per cent butter, and the water extracted syrup that came from the navy bean, in same percentage as it came out.

Average daily consumption per gram rat, 0.060.

Average gain in weight per rat, 0.50%.

Condition of rats at end of three days diet period, normal.

EXPERIMENT XVI.

Cooked Soy Oil and Steam Distillate from Soy Meal

Rats I, II and III were fed on a diet consisting of 67 per cent cooked soy bean oil, and extracted meal, in same proportions as in the original, and 33 per cent butter.

Average daily consumption per gram rat, 0.040.

Average gain in weight per rat, 0.08%.

Condition of rats at end of three days diet period, restless.

Rats IV, V and VI were fed on a diet consisting of the steam distillate from the soy meal put in same quantity of balanced ration as meal from which it was distilled, and butter in ratio of 67 to 33.

Average daily consumption per gram rat, 0.056.

Average gain in weight per rat, 0.41%.

Condition of rats at the end of three days diet period, normal.

EXPERIMENT XVII.

In this experiment the six rats were fed on a diet of the same balanced ration used in Experiment VIII, excepting that it was barely moistened with benzine and spread thinly over paper and placed in a slight current of air, and dried for twenty-four hours. The daily consumption was recorded and found to be somewhat like that of Experiment VI, increasing slightly as the days progressed. On account of their eating more of the balanced ration than of the soy or navy meal we could notice better the daily increase.

The daily consumption for all the rats averaged per gram rat 0.046, as against 0.058 in the balanced ration, which indicated that the benzine had

not completely evaporated away. This showed us what allowance to make over the average daily consumption of the benzine extracted meals in Experiment VI.

EXPERIMENT XVIII.

In this experiment all of the six rats were fed on the same diet as in Experiment XVII, excepting that alcohol was used instead of benzine. The daily consumption was found to be somewhat like that of Experiment VII, only in this experiment we had to figure out the average for each day in order to tell that they increased as the days progressed.

The daily consumption for all of the rats in this experiment averaged per gram rat 0.051 as against 0.058 when the balanced ration was not so treated, which indicated that the alcohol had not completely evaporated away, and showed what allowance should be made for this in Experiment VII. It showed also that the alcohol was not quite as distasteful to the rats as was benzine.

EXPERIMENT XIX.

In this experiment we extracted the soy meal for fifteen minutes with a ten per cent solution of sodium bicarbonate. Some of the household preparations are made this way just before cooking, with the idea that the flavor is improved, and that a bitter poisonous substance is removed. The rats made a very slight difference in their daily consumption. The average was 0.038. That of the unextracted meal was 0.033.

When the navy bean meal was treated the same way as the soy meal the daily consumption was increased from 0.021 to 0.027, a little greater proportion than in the soy product. In order to carry the test further, we evaporated the extract and put solids back into the same balanced ration as we did with the extracts in previous experiments.

EXPERIMENT XX.

Rats I, II and III were fed on a diet of balanced ration with the soda extract added in the same proportion in which it had been extracted from the soy bean, together with solid sodium carbonate that had to go with it, which was about five grams of the carbonate in fifty grams of the meal. This lowered the daily average consumption from 0.058 for the balanced ration to 0.054 for the same ration with the extract and salt in it.

Rats IV, V and VI were fed on a diet like that above only navy bean soda extract was used. The extract and solid soda in this case lowered the average consumption from 0.058 to 0.054. The extracts added to the balanced ration did not lower its consumption as much as their removal from the meals raised it.

Chart I represents a summarized comparison of the results of a few of the diet experiments with those of the first balanced ration experiment, and also with those of the second balanced ration experiment which is No. VIII in the list.

The full extent of the bars, in all three of the following charts, which measures 63 mm., represents the 0.063 grams, daily consumption per gram rat of the first balanced ration, (Exp. I). The dark portion of each bar represents the daily consumption of the experimental diet, and the half dark portion the approximate amount of clover or succulent vegetable material consumed.

The half dark portion is not continued in Chart II or Chart III for the reason that we noted no definite relation existing between this and the dark portion in Chart I.

CHART I

Exp. No.

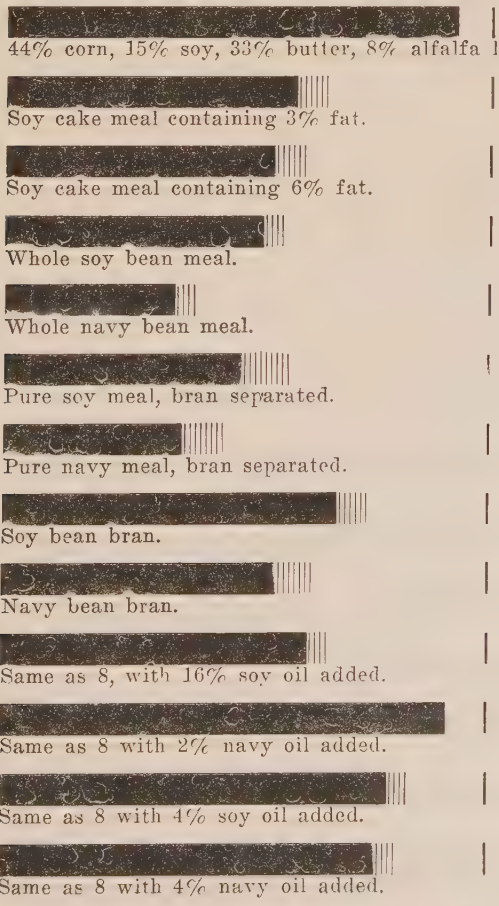

8 44% corn, 15% soy, 33% butter, 8% alfalfa leaf meal.
2. Soy cake meal containing 3% fat.
Soy cake meal containing 6% fat.
3. Whole soy bean meal.
Whole navy bean meal.
4. Pure soy meal, bran separated.
Pure navy meal, bran separated.
5. Soy bean bran.
Navy bean bran.
9. Same as 8, with 16% soy oil added.
Same as 8 with 2% navy oil added.
10. Same as 8 with 4% soy oil added.
Same as 8 with 4% navy oil added.

Chart II represents a summarized comparison of the results of a few of the diet experiments with those of the first balanced ration, and also with those of the balanced ration moistened with benzine, (Exp. XII), to which we wish to make especial comparisons of the diets on materials which were products of the benzine extraction.

In this chart are also represented the results of Exp. XIII on the balanced ration, moistened with alcohol; followed by experiments on diets of the products of alcohol extraction.

The balanced ration experiment (Exp. No. VIII) is also represented in the same chart for the purpose of comparing it with the standards represented by No. XII and XIII.

CHART II.

Exp. No.

12. Balanced ration moistened with benzine and dried.

6. Soy meal, bezine extracted.

Navy meal, benzine extracted.

16. Soy meal, benzine extracted, cooked soy oil replaced.

13. Balanced ration moistened with alcohol and dried.

7. Benzine and alcohol extracted soy meal.

Benzine and alcohol extracted navy meal.

9. Balanced ration as in 8.

11. As in 8 and alcohol extracted carbohydrates from soy bean.

As in 8 and alcohol extract and carbohydrates from navy bean.

12. As in 8 and organic acids from soy bean.

As in 8 and organic acid from navy bean.

13. As in 8 and waxes from soy bean.

As in 8 and waxes from navy bean.

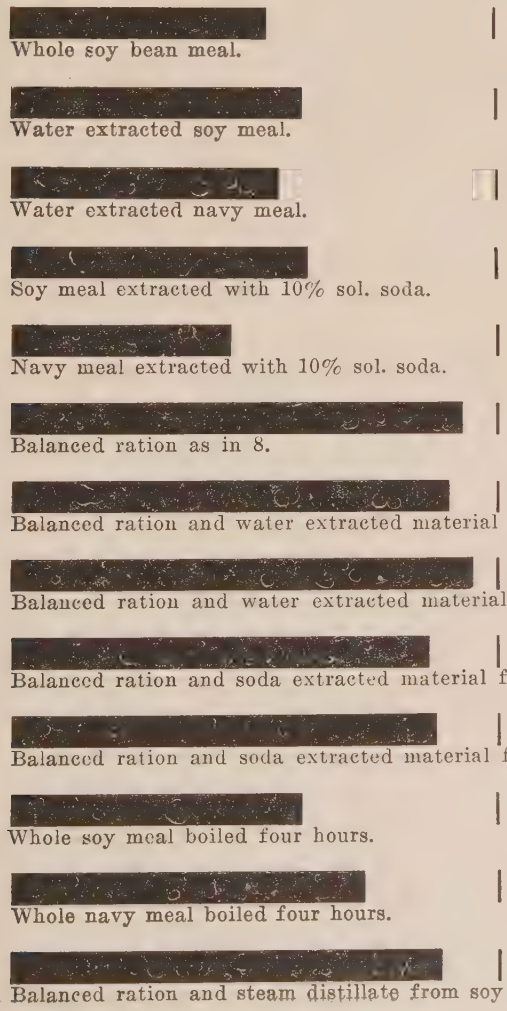
Chart III is introduced by a bar representing the results of the experiment with whole soy bean meal, and followed up by results from various extracted and extraction products.

A bar representing the results of the balanced ration No. VIII is again inserted about the middle of this chart and followed by results from the addition of various extracted materials to the balanced ration.

Results from experiments on the cooked products are also represented on this chart.

CHART III.

Exp. No.


3a. Whole soy bean meal.
14. Water extracted soy meal.
Water extracted navy meal.
19. Soy meal extracted with 10% sol. soda.
Navy meal extracted with 10% sol. soda.
8. Balanced ration as in 8.
15. Balanced ration and water extracted material from soy meal.
Balanced ration and water extracted material from navy meal.
20. Balanced ration and soda extracted material from soy meal.
Balanced ration and soda extracted material from navy meal.
3b Whole soy meal boiled four hours.
Whole navy meal boiled four hours.
16b. Balanced ration and steam distillate from soy meal.

A Steam Distillation for the Purpose of Separating the Objectionable Flavor

Five hundred grams of the whole meal were moistened with water and distilled with steam for an hour. The distillate was caught in four different equal portions about 50 cc. each. The last two portions had no noticeable odor. The second portion had the least bit of a beany odor. The residue in the flask still retained the characteristic soy bean odor, and had the characteristic taste of the cooked soy bean meal.

The first portion of the distillate standing in an uncorked flask over night lost most of its beany flavor. It lost the beany flavor entirely by standing twenty-four hours. The second portion of the distillate had lost its beany odor entirely by standing in an uncorked flask over night.

Another steam distillation of another five hundred grams was made for fifteen minutes. The distillate was corked tightly, and each morning one-third of it was removed and mixed with the balanced ration referred to above and fed to the rats in the same proportion in which it came from the meal. There was no appreciable difference in the way the rats ate this and the way they ate the balanced ration. The beany odor disappeared from the mixture in a few hours.

Another steam distillation of another five hundred gram portion of the meal was made for fifteen minutes. The distillate was immediately shaken with ether, the ether layer separated and the ether evaporated. There was not enough residue left for analysis, nor would we, in our judgment, have secured enough in ten distillations.

DISCUSSION OF RESULTS

The question naturally arises: Why have the results from the foregoing experiments in the determination of the digestibility of the proteins of the soy cake meal been in both cases higher, (p. 291), than the results obtained by Mendel and Fine (35) and others, for the proteins of the whole soy bean meal? Obviously it is the same protein in both cases, yielding on digestion the same amino acids.

First: The most important consideration must be given to the fact that the protein of the soy cake meal is not accompanied by nearly so large an amount of soy bean oil as is that of the whole bean meal. There is the possibility that the larger amount of oil in the whole bean meal contained sufficient amounts of some constituent to slightly inhibit certain enzymic action or to be responsible for premature defecations,—conditions which would result in lower digestibility factors for the whole bean meal (37) (38).

Second: If we had any correct method of estimating what these authors' results would have been had they made the same sort of metabolic allowances; or of determining what our results would have been had we not been compelled to make such allowances, on account of the standards for the milk and the flour used, our results might not have been any higher than theirs. We would rather attach more importance to the first reason, and consider the point in favor of the soy cake meal.

The almost complete digestibility of the vegetable gums and dextrins of the soy bean (p. 300) would lead us to the conclusion that they are not

very complex in their structure, and, if there is such a thing as one kind of vegetable gums being simpler in structure and nearer to the dextrose than is another, the vegetable gums of the soy bean belong to that class. The fact that some of the earlier experimenters estimated that there existed in the soy bean from nine (53) to twelve (51) per cent cane sugar, and reported no raffinose, no dextrose, dextrin or dextran would tend to lead us to the conclusion that these experimenters estimated the bodies of this class with the cane sugar, and perhaps with their extracting agents these bodies behaved in the same manner as cane sugar. As far as digestibility and food value is concerned they appear to be just as good as cane sugar. The amount of these carbohydrates found by these determinations,—(6.65) added to the sucrose, raffinose and invert sugar,—(3.56) amounts to 10.21, about the same as the earlier investigators found and estimated as cane sugar.

The high digestibility factor of the hemicelluloses of the soy bean as extracted with dilute hydrochloric acid, compared to the low digestibility factor for some hemicelluloses (25) (55), would lead to the suggestion that hemicelluloses in general are variable in complexity of structure somewhat like the protein materials, and that some hemicelluloses are "near sugars," and that others are almost true celluloses. And, we might reasonably conclude that the hemicelluloses of the soy bean are very much nearer to the sugars in composition and structure than they are to the true celluloses. As far as digestibility and nutritive value are concerned they appear to be almost as valuable as sugars.

When we consider the proportion of the milled products of the soy bean, (8% bran and 92% meal) as we found them in an accurate separation, (p. 301), or allowing in the cruder milling operations for 10% waste in the elimination of all that might be termed bran, we would have to find either a very low digestibility factor for the bran, or find in it some harmful element not found in the meal, if we could consider ourselves justified in going to the expense of operating the milling processes. We have found only about 20% of the bran as a whole indigestible. Since 20% of 10 is 2% of 100, we see that as far as digestible matter is concerned we would gain only 2% by operating the milling processes.

As far as physical appearance is concerned, we found the bran to possess a rather objectionable feature. It has what might be termed a dirty opalescence, while the meal has what would be called a rich golden color. The removal of the bran probably increases the golden richness in color of the meal about 10 per cent.

The difference made in the proportions of the mineral contents of the soy meal by the removal of the bran (lowering the CaO from 0.31% in the whole meal to 0.27% in the pure meal, or 0.04% (p. 304), and increasing the P_2O_5—from 1.42% in the whole meal to 1.52% in the pure meal, or 0.1% (p. 305), would not be of material consideration in estimating the expenses and profits of the milling process.

The traces of alkaloids were found in both the bran and the meal. No other poisons were found in either product, with the exception of a trace of

tannin in the meal. No notable physiological effects were experienced by the subject, making a day's ration solely on the bran. So the 2% increase in food value and the 10% gain in physical appearance of the meal is all that would be gained by the milling process applied to the soy bean.

In Experiment I with the rats, we notice that all of the rats consumed on an average of .063 grams of food per gram rat per day. By the second and third experiments, we see that of the different samples of soy meal they ate only 0.035 and 0.033 grams of food per gram rat per day, just a little more than half of what they did of the balanced ration. The presence in the first diet of the non-nutritious agar, and the presence in the second and third diet of more butter, might have accounted for some of the difference, but not very much. So we must conclude that the soy bean has in it something that is distasteful.

In the second experiment we note that the rats, fed on the soy cake meal which had three per cent of oil left in it, ate 0.038 while those on that which had six per cent of oil ate 0.035, hardly enough difference to justify us in drawing the conclusion that the oil had anything to do with the flavor. But, when we note in experiment three that the rats on the diet of whole soy meal ate only 0.033, we suspicion that the oil may have something to do with the disagreeable flavor. Again, in Experiment IV, the rats were fed on a diet of pure soy meal, from which nothing was separated except the bran. This has a very small proportion of oil and leaves the meal with more oil in proportion. Of this, they ate only 0.030, and we get more evidence in support of the idea. In Experiment VI, in which we fed three of the rats on soy meal with practically all of the fat extracted with benzine, they ate on an average of 0.031, but in a later experiment XVI, in which we merely dampened the balanced ration with benzine, same as we did in Experiment VI, they ate only 0.046, whereas they ate 0.058 of the same balanced ration when it was not so treated. This makes it appear as tho the benzine, which had not been completely driven from the meal, was largely responsible for the disagreeable taste in this diet.

In Experiment VIII, we found that the rats consumed on an average of 0.058 grams of a balanced ration, a ration which was agreeable to their taste; while when fed on the same ration with sixteen per cent of soy oil mixed with it, as seen in Experiment IX, they ate only 0.040.—only a little over two-thirds as much. And, in Experiment X, in which they had the same balanced ration with only four per cent of soy oil, they consumed 0.050, a little over five-sixths as much as with no oil at all. These two latter experiments reinforce the idea that there is a disagreeable flavor in the soy bean oil, and that as far as the oil is concerned we have a better flavored food in the commercial soy cake meal than in the whole bean meal.

Following up the same experiments with regard to the navy bean oil, we find in Experiment III that the rats, fed on the whole navy meal, ate 0.021. This for the navy meal is only one-third of what they ate of the balanced ration and about two-thirds of what they ate of the soy meal under the same conditions. We see in Experiment VI that they increased this a little, (to 0.026) when the oil was extracted. But, we see by comparing Experiment VIII with Experiment IX that the restoration of the navy bean oil made

no difference in the amount which they ate before the oil was put back and afterward. Then, when we put into the balanced ration four per cent of navy oil, we found as in Experiment X that it did make some difference, bringing their average down from 0.058 to 0.049. This indicates that in the raw navy bean there is something distasteful. It shows, too, that the flavor might be due in part to the oil, if there was sufficient of the oil in the navy bean. It appears then, so far as the oils of the two beans are concerned, that one is as distasteful as the other.

Experiment VII shows that the rats will eat the soy meal with a little more relish when it is extracted with hot 95 per cent alcohol. The amount eaten in this experiment compared to what they ate in Experiment VI, which is 0.035 as against 0.031, and indicates that the alcohol also has removed something distasteful or that the alcohol, itself, which was not dried off from the material, is not so distasteful as is the benzine. Experiment XVII, in which the rats were found to eat 0.051 compared to the 0.058 of Experiment VIII, the only difference being that the balanced ration of Experiment XVII was barely moistened with alcohol and then allowed to dry for twenty-four hours, shows that the alcohol does interfere with the taste to some extent, but not so much as does the benzine. This fact would add a little to the indications that the alcohol takes away something that is distasteful. In Experiments XII and XIII, in which the organic acids and waxes respectively were added to the balanced ration in the same proportions in which they were extracted from the meal, the rats ate 0.044 for the acids and 0.045 for the waxes as against 0.058 for the food without them. This confirms the opinion that the alcohol takes away some of the disagreeable flavor. Experiment XI, the alcohol extracted sugars were added to the balanced ration in the same percentage as extracted. Of this, the rats consumed 0.055 grams, showing that the disagreeable taste is not in the sugar fraction of the alcohol extract, but in the organic acids and wax, and is about equally divided between the two.

Following thru the same experiments with the navy bean meal, we find that the alcohol extraction raises the navy meal in the rats' estimation from the amount of 0.026, benzine extracted to the amount of 0.040 alcohol extracted; while for the soy bean the increase was merely from 0.031 to 0.035. Adding the alcoholic extract of the navy bean to the balanced ration reduced the average consumption from 0.058 to 0.046, 0.045, 0.048 for the carbohydrates, acids and waxes respectively; as can be seen in experiments XI, XII and XIII, respectively. These experiments show that by far the greater portion of the disagreeable flavors of the navy bean exist in the alcohol extracted materials, about equally distributed among the carbohydrates, acid and wax mixtures.

Experiment V, in which the bran was discarded in case of both the soy and the navy bean meal, we find an average consumption of 0.022 for the navy and 0.030 for the soy, showing that as far as flavor is concerned there is no point in removing the bran from either bean.

Experiment V, in which the bran alone was fed, shows an average consumption of 0.036 for the navy and 0.043 for the soy, a considerable increase over that of the whole meal or pure meal in each case. This is

what we would expect as far as the flavor of the soy bean oil is concerned, for in our analysis we found less than two per cent of oil in the soy bran. As far as the taste of the acids and waxes is concerned, it is a little different than might be expected, for we found that the bran contained twice the percentage of acids and about three times the percentage of waxes found in the meal. But, on the other hand there is more tasteless material and more material that has an agreeable flavor in the bran than in the meal because it contains a larger amount of fiber and carbohydrates. Then, if the whole meal is used, since only eight per cent of the whole meal is bran, the bran could not be depended on to influence the taste one way or another.

By Experiments XIV, XV, XIX and XX we find that neither water nor soda extractions make appreciable difference in the flavor of the products.

From the above considerations, it would seem quite evident that the soy cake meal furnishes a little better food than does the whole soy bean, and that it comes much nearer furnishing a substitute for meat than does the navy bean.

SUMMARY

Porridge made of soy cake meal well cooked, which was considered rather distasteful at first, was not considered so distasteful after eating three or four meals. It becomes very palatable after a three or four days' diet on it.

There are no apparent discomforts in man from a diet consisting of soy cake meal, milk, butter and sugar, the soy bean meal furnishing 25 per cent of the calories.

The protein of the meal when thoroly cooked is about 91 per cent digestible by man (making metabolic corrections.) This compares favorably to the proteins of patent wheat flour.

The carbohydrates as a whole, altho consisting largely of dextrin, pentosan and galactan, are about 94 per cent digestible.

A more extended study of the digestibility of the different carbohydrates taken separately proves that the sucrose, which amounts to about 3 per cent, is practically 100 per cent digestible; that the raffinose, which amounts to about 1 per cent, is thoroly digestible; that the dextrans or dextrins are essentially 100 per cent digestible; that the little bit of starch, amounting to less than one per cent, is thoroly digestible; that the hemicelluloses, amounting to about six per cent, are about 93 per cent digestible, and that the cellulose is about 77 per cent digestible.

The bran can be separated easily from the soy bean by milling. It can be more easily and more completely separated than can the bran of wheat. The bran makes up about eight per cent of the soy bean and is composed mainly of crude fiber and nitrogen free extract. The crude fiber amounted to about 37% and the nitrogen free extract amounted to about 43%.

Digestibility experiments on the bran showed that the nitrogen free extract, including the hemicelluloses and the waxes, is about 84% digestible, which is much less than that of the whole bean. This we judge is on account of the large amount of waxes in the nitrogen free extract of the bran.

A diet consisting of well cooked soy bean bran appeared to have no ill effects physically or physiologically. No noticeable amount of gas indicating fermentation, as is the case with the navy bean bran, was noticed with the soy bean bran. One day's diet exclusively of the bran produced small amounts of gas, but nothing especially distressing. However, the bran diet was unpalatable.

The calcium oxide content of the bran was found to be 0.8% and that of the meal 0.27%. The removal of the bran from the bean lowers the calcium oxide content from 0.31% to 0.27%, or a lowering of 0.04%.

The phosphorus pentoxide content of the bran was found to be 0.27%, and that of the meal to be 1.52%. The removal of the bran from the bean raises the phosphorus pentoxide content from 1.42% to 1.52%, an increase of 0.1%.

No salicylic acid was found in either the bran or the meal. No hydrogen cyanide or cyanates were found in either the bran or the meal of the samples tested.

A very slight trace of tannin was found in the meal, but no trace of tannin could be found in the bran. A slight trace of alkaloids was found in both the meal and the bran.

The raw soy bean meal seems almost as distasteful as is the navy bean meal, judging from our experience with white rats.

Soy bean oil contains some of the unpleasant flavor found in the bean. Cooking does not improve the flavor of the oil very much.

A little of an unpleasant flavor was found to be present in the navy bean oil. Cooking made very little improvement in this case.

A disagreeable flavor was found in the organic acids of the soy bean. This was practically all removed by cooking. The same sort of flavor of the navy bean exists in the carbohydrates, acids and waxes about equally distributed. Cooking makes great improvement in this case.

As far as flavor is concerned there is no point gained in removing the bran from either the soy bean or the navy bean.

The beany flavor and some of the disagreeable taste can be easily removed from the soy bean by steam distillation, but the disagreeable flavor in the oil cannot be removed in this way.

The greater part of the laboratory work for the above article was done in the laboratory of the Department of Agriculture and Soils, in the Ohio State University, under the leadership of Dr. J. F. Lyman. The article was submitted and approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy granted by the Ohio State University in 1919.

The author wishes also to thank Dr. Park of the Farm Crops Department of the same university for his suggestions concerning the milling of the soy bean and for the use of his mills in the process.

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